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ADVANCED AIRCRAFT ELECTRICAL SYSTEM (A

Definition and Prototype Design for F-14 Aircraft

Volume 1: Technical

Grumman Aerospace Corporation
Bethpage, New York

JULY 1976

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This report describes the application of advanced electrical power generation and distribution concepts to the F-14A aircraft. The study is designed to provide a baseline from which the concepts of the Advanced Aircraft Electrical Systems (AAES) can be developed and tested in the laboratory and on a prototype aircraft. The Navy F-14A aircraft was used as the vehicle to which the study concept was applied, and from which the study data base was developed. →

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Two advanced power generation concepts, Variable Speed Constant Frequency (VSCF), and Constant Frequency Generator-DC Link (CFG-DC) were investigated. The Solid State Electric Logic (SOSTEL) system was used to provide power distribution. This system employs data bus/remote terminal concepts, solid state transducers, and solid state power controllers to provide the control, protection and power interlocks presently implemented on the aircraft by electromechanical devices (switches, circuit breakers and relays).

This preliminary design study identifies the system, hardware/software, operational, installation, thermal, reliability, and flight test requirements for the application of AAES to a prototype aircraft.

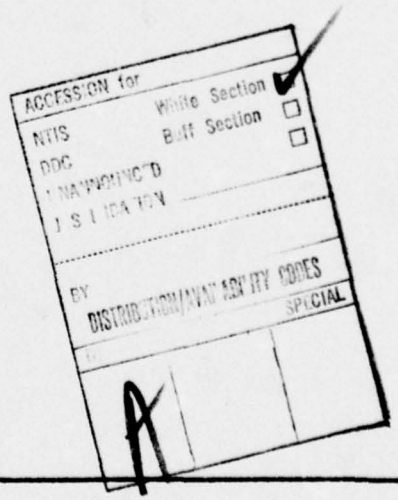


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LIST OF ABBREVIATIONS AND ACRONYMS

AAES	Advanced aircraft electrical system
AAI	Air-to-air identification
AIMIS	Advanced integrated modular instrumentation system
ACLS	Automatic carrier landing system
ACM	Air combat maneuver
ADC	Air data computer
ADF	Automatic direction finding
ADI	Analog display indicator
AFCS	Automatic Flight Control System
AHRS	Attitude heading reference set
AICS	Air inlet control system
AIM	Air intercept missile
ALTM	Altimeter
AUX BRK	Auxiliary brake
BIRAM	Bit input random access memory
BL	Butt line
BT	Bus tie
CB	Circuit breaker
CCDP (CC&D)	Crew control and display panel
CCU	Cable control unit
CFG	Constant frequency generator
CPRSN	Compression
CSD	Constant, speed, drive
CSDC	Computer signal data converter
DECM	Defensive electronic countermeasures
DEMUX (DMUX)	Demultiplexer
DES	Designator
DT	Data terminal

EAC	Emergency a-c contactor
ECM	Electronic countermeasures
EDC	Emergency d-c contactor
ESS	Essential
ETI	Elapsed time indicator
EXT	External
EXC	External contactor
FDR	Feeder
FLT	Flight
FS	Fuselage station
GAC	Grumman Aerospace Corporation
GEN	Generator
GCU	Generator control unit
GPM	Ground power monitor
GPMS	General purpose multiplex system
HDL	Handle
HSD	Horizontal situation display
HUD	Heads-up display
HVDC	High voltage d-c
ICS	Intercommunication system
IDENT	Identification
IDG	Integrated drive generator
IFF	Identification friend or foe
ILS	Instrument landing system
IMU	Inertial measurement unit
INTLK	Interlock
IRAM	Input random access memory
I/O	Input/Output
IWSFD	Integrated weapon systems functional diagrams

LDC	Left main d-c contactor
LED	Light emitting diode
LGRB	Left glove relay box
LMC	Left main contactor
LMLG	Left main landing gear
LWOW	Left weight on wheels
MCB	Mid-compression bypass
MDR	Multiplexer driver receiver
MLG	Main landing gear
MMD	Master monitor display
MUX	Multiplexer
MSL	Missle
MTBF	Mean time before failure
MU	Master unit (processor)
NADC	Naval Air Development Center
NFO	Naval Flight Officer
NLG	Nose landing gear
OBC	Onboard checkout
ORAM	Output random access memory
OVSP	Over speed
PGS	Power generating system
PP	Pilots panel
PROM	Programmable read only memory
PMS	Phoenix Missle System
QAD	Quick assembly disconnect
RAM	Random access memory
RCCB	Remote controlled circuit breaker
RDC	Right main d-c contactor
RIT	Remote input terminal

RGRB	Right glove relay box
ROM	Read only memory
ROT	Remote output terminal
RMC	Right main contactor
RMLG	Right main landing gear
RWOW	Right weight on wheels
SAS	Stability Augmentation System
SIU	Standard interface unit
SOSTEL	Solid state electric logic
SSPC	Solid state power controller
TID	Tactical information display
TR	Transmit receive, transformer rectifier
UMB	Umbilical
VDI	Vertical display indicator
VSCF	Variable speed constant frequency
WCS	Weapon control system
WL	Water line
WOW	Weight on wheels
WRA	Weapon replaceable assembly

Section 1

INTRODUCTION AND SUMMARY

This is the final engineering report describing work performed by Grumman Aerospace Corporation under Naval Air Development Center Contract N62269-75-C-0392 of June 30, 1975. This work was performed to provide a realistic baseline for the development of the Advanced Aircraft Electric System (AAES). The Navy F-14A aircraft was utilized as the baseline vehicle about which the study concept was applied and from which the study data base was developed.

The AAES is a system employing advanced concepts for aircraft power generation and distribution. It is designed to replace the existing integrated drive generators and the electromechanical switching and distribution of power presently utilized in the majority of aircraft. The AAES consists of the Solid State Electric Logic (SOSTEL) and the General Purpose Multiplexing Systems (GPMS) for power control, distribution and protection. It utilizes a constant frequency generator (CFG) for primary aircraft power generation.

The SOSTEL/GPMS systems employ multiplexing and time division data bus concepts for the transmission of information and are consistant with MIL-STD-1553A data bus formats and requirements. GPMS is an advanced concept employing remote data terminals (DT's), a central cable control unit (CCU) and twisted pairs, coaxial cables or fiber-optic technology data bus transmission mediums. It is a general-purpose, nondedicated asynchronous system capable of interfacing with a wide variety of signal types. Its application includes flight control, weapon control, display, communication, navigation, and identification subsystems as well as power distribution and control. In this study it was primarily viewed as a system which would provide the transmission facilities (data buses) for the SOSTEL system. This implies that the system analysis and requirements for the implementation of a complete GPMS system was not performed. However, its interface

and operation as applied to SOSTEL were examined. In particular the operation of a synchronous, time-shared SOSTEL command response system was examined relative to its operation as part of an asynchronous GPMS polling system. In addition, it is utilized to provide sink and source terminals for signals which were not compatible with the SOSTEL system.

The SOSTEL system is capable of providing, either in conjunction with GPMS or by itself, the control and distribution capability of an aircraft power distribution system. It utilizes solid state power controllers to provide the power switching and protection presently implemented by electromechanical circuit breakers, relays and switches. It utilizes solid state transducers as replacements for the present power control signals sources (manual, mechanical, thermally, pressure actuated switches, etc). Remotely located demultiplexers (DEMUX) and multiplexers (MUX) are employed to control the solid state power controllers and sample the solid state transducers. Master units (MU's) containing digital processors provide control of the SOSTEL system as well as solutions to the power Boolean equations. These equations are equivalent to the present power paths, where power leads are routed through the aircraft switches and relays for power control to a weapon replaceable assembly (WRA).

The constant frequency generator (CFG) provides a precise frequency output when driven by a variable speed input. The CFG system consists of a conventional oil cooled generator, a static converter, and control and protection circuitry. This system can be installed either as a single package direct replacement for the existing IDG unit (utilizing the dc link approach to produce constant frequency) or as a variable frequency generator mounted to the engine. In this latter concept, ac is fed to a cycloconverter installed in the aircrafts fuselage which changes the variable frequency power to constant 400 Hz, 3-phase power output. The selected CFG is compatible with the existing IDG cooling loop and mounts directly on the present engine drive pad. Generator design is optimized through use of an integral step-up gear box.

The CFG eliminates the need for a constant-speed drive, uses a brushless exciter concept, and uses solid state circuits for long life and easy maintenance. In addition, the ability to easily provide split synchronized or parallel operation results in a simpler bus and distribution configuration. An alternate, near-term, HVDC-approach involves the use of a separately packaged system consisting of a generator and rectifier providing a 270 volt d-c output, and a power conditioning unit providing 400 cycle a-c and 28 volt d-c.

The F-14 power generation and distribution system was analyzed, the loads, transducers, and power Boolean equations were catalogued. This information was used to identify the number and types of components in the GPMS/SOSTEL system. A physical review of the F-14 identified locations for installation of components. A thermal analysis was performed to ensure the survival of the components in their assigned locations. A preliminary reliability analysis of the AAES system and components was performed. Various PGS configurations were analyzed, the internal redundancy requirements of the SOSTEL Group III components were reviewed, and the thermal/reliability requirements of the solid state controller configurations and installations were identified. The requirements and routines required by the master unit processor were examined to determine the memory and computational load requirements. In addition, the SOSTEL interface to the power generation system was analyzed to identify the parameters the SOSTEL system would monitor to ensure compatibility between power generation and power distribution. SOSTEL priorities and techniques for providing power to essential loads during emergency modes of operation were developed using the present F-14A aircraft multibus configurations as a baseline.

The crew control and display (CCDP) design requirements were investigated and an alphanumeric interactive control display unit is described. The design of breadboard MUX and DEMUX terminals configured about "dual" in-line MSI and LSI as well as a "Smart" unit utilizing an Intel 3000 microprocessor is discussed. The installation, thermal, reliability and mechanical considerations and design of an AAES-configured F14-A was developed.

Section 2

OBJECTIVES

The primary objectives of the study are:

- Provide a realistic baseline of actual aircraft data for developing, sizing, and configuring the AAES system
- Identify the thermal, mechanical, and reliability impact of AAES components and system
- Provide a quantitive comparison of an AAES-configured F-14 vehicle with a standard F-14A aircraft
- Identify problems and recommend solutions associated with AAES and its implementation in an aircraft
- Identify the requirements for an AAES laboratory system and a subsequent prototype flight system
- Identify areas where additional research and development are required.

Section 3

SYSTEM DEFINITION

The AAES-PGS/SOSTEL System and F-14A requirements are utilized to generate various configurations of the AAES. The present F-14A system is described. A prototype system for future two-engine aircraft is presented as well as two near-term minimum flight demonstration systems and a laboratory system.

3.1 PRESENT F-14A SYSTEM

The present F-14 PGS and distribution system are illustrated in Fig. 3-1. Two engine driven, oil-cooled, integrated drive generators (IDG's) produce the normal 115/200-vac, 400-Hz, 3-phase electrical power. The normal rated output of each generator is 75 kva, which is sufficient to individually assume the complete electrical load of the aircraft. One IDG, consisting of a generator and a constant speed drive (CSD) is on the accessory gear box of each engine. Generator control units (GCU's) individually monitor the output voltage and frequency of the generators, and control the application of power to the a-c buses via the LMC and RMC contactors. Two transformer rectifiers (TR's) rated at 100 amp each, convert internal or external 115 vac power to 28 vdc power. They are fed via circuit breakers (CB's) from the left and right main a-c buses. External power is applied through a receptical forward of the port engine, its quality and application to the main a-c buses via the external contactor (EXC) is monitored and controlled by a ground power monitor and control unit. A hydraulically-driven emergency generator (rated at 5 kva, 115/200 volts and 50 amperes, 28 vdc) provides a limited, but independent, backup power source. Thirteen buses are fed by the power sources via contactors to provide a basically normal split bus configuration and a number of emergency configurations. Three hundred and twenty-three circuit breakers located in 10 circuit-breaker panels feed the aircraft electrical loads and provide isolation and protection between the loads and buses. Downstream of the circuit

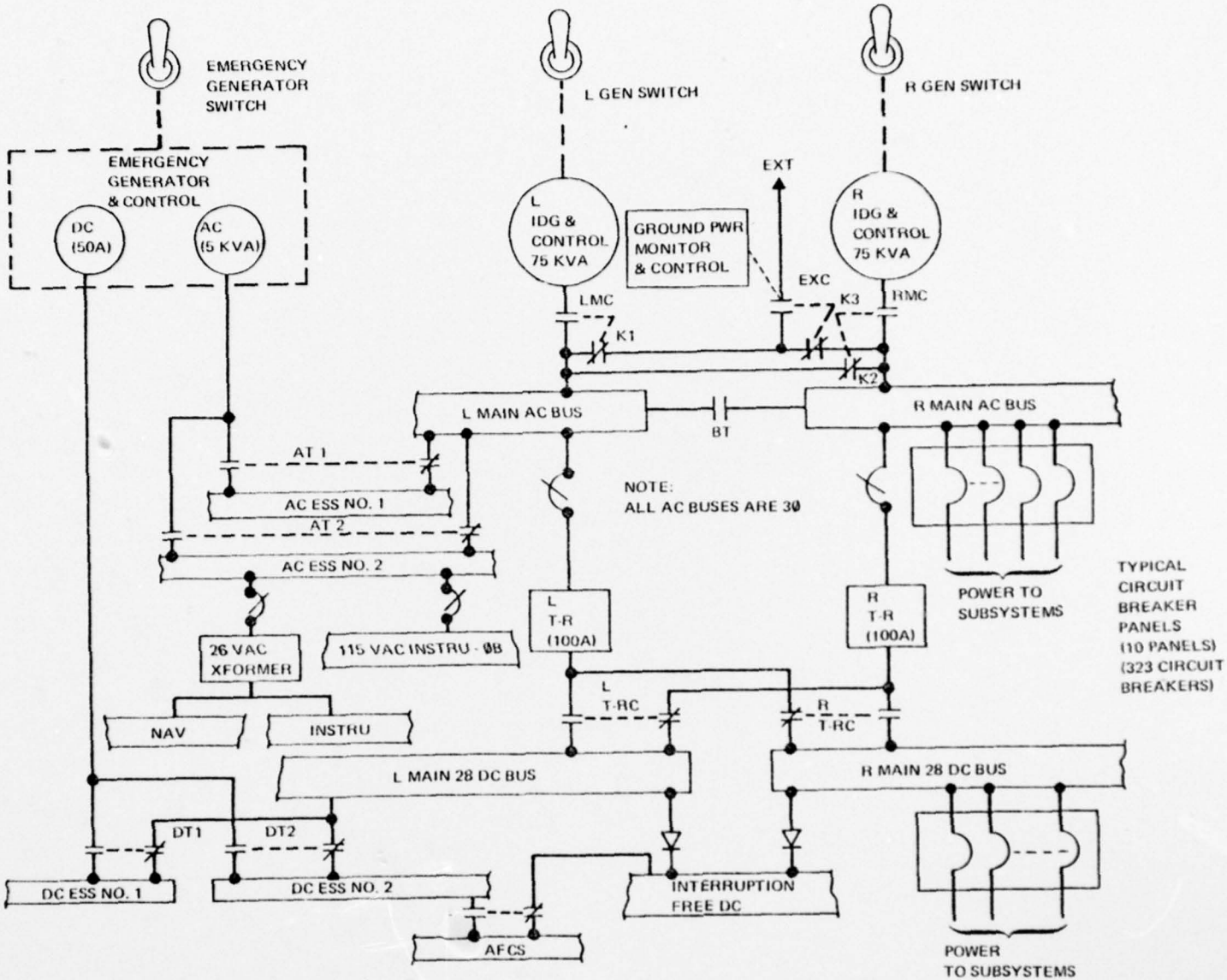


Figure 3-1. F-14A Power Generation and Distribution

breakers, the distribution of power to the loads can be generally divided into two classes: a) loads which are powered-on whenever the buses are energized, and b) loads which are powered via switching elements.

This system contains three control switches and three caution advisory lights. The control switches, located on the pilot's generator panel, are: left generator switch, right generator switch, and emergency generator switch. The left and right generator switches have three positions each a) NORMAL, b) OFF/RESET, and c) TEST. The emergency generator switch has two positions; a) NORMAL and b) OFF/RESET. The three caution advisory lights (left generator, right generator, and transformer rectifier) are used in conjunction with the control switches to inform the pilot of the PGS configuration or failures in the system. Table 3-1, Electrical Power Configurations and Indications, illustrates the significance of the various switch and light conditions relative to the PGS configurations.

A general overview of the system operation follows:

The F-14A PGS utilizes a split-bus a-c and d-c configuration. Each generator or transformer rectifier is capable of supporting the entire a-c or d-c loads, respectively. External a-c power is supplied via an external connector and EXC contactor to the left and right main a-c buses. External power application is monitored for power quality and controlled by the ground power monitor unit. When external power is applied, all buses (ac and dc) are energized. Similarly, all nonswitched loads are energized via their closed circuit breakers being fed by the buses. Either engine may then be started. If the right engine is started first and is up to speed the right contactor (RMC), controlled by its respective control unit, will close. The right generator will supply power to the right main buses while the left buses are supplied by external power. When the left engine is started and up to speed, the left generator contactor (LMC) will close, supplying power to the left main buses. The external connector may then be removed.

TABLE 3-1. ELECTRICAL POWER CONFIGURATIONS AND INDICATIONS
(SHEET 1 OF 2)

MASTER GEN Control Panel Switch Positions												Condition (See list below)
L Gen Switch	R Gen Switch	EMERG Switch	Ext Pwr	Engines L	Engines R	Emer Gen	Transformer Rectifier L	Transformer Rectifier R	Pilot CAUTION ADVISORY Indicator Lights L GEN	Pilot CAUTION ADVISORY Indicator Lights R GEN	Pilot CAUTION ADVISORY Indicator Lights TRANS/RECT	
OFF	OFF	NORM	on	inop	inop	inop	opr	opr	on	on	off	1
ON	ON	NORM	off	opr	opr	inop	opr	opr	off	off	off	2
ON	ON	NORM	off	opr	opr	inop	opr	opr	on	off	off	3
ON	ON	NORM	off	opr	opr	inop	opr	opr	off	on	off	4
ON	ON	NORM	off	opr	opr	inop	inop	opr	off	off	on	5
ON	ON	NORM	off	opr	opr	inop	opr	inop	off	off	on	6
ON	ON	NORM	off	opr	opr	opr	No power to transformer rectifiers		on	on	on	7
ON	ON	NORM	off	inop	inop	opr			No power to lights			8
TEST	ON	NORM	off	opr	opr	inop	opr	opr	off	off	off	9
TEST	ON	NORM	off	opr	opr	inop	opr	opr	on	off	off	10
ON	TEST	NORM	off	opr	opr	inop	opr	opr	off	off	off	11
ON	TEST	NORM	off	opr	opr	inop	opr	opr	off	on	off	12

Conditions:

1. External electrical power on; engines not operating
2. Normal flight configuration
3. Left alternating-current generator system failure (generator or control unit)
4. Right alternating-current generator system failure (generator or control unit)
5. Left transformer rectifier failure
6. Right transformer rectifier failure

TABLE 3-1. ELECTRICAL POWER CONFIGURATIONS AND INDICATIONS
(SHEET 2 OF 2)

Conditions (cont):
7. Both generator-transmissions inoperative; at least one engine operating
8. Both generator-transmissions inoperative; both engines windmilling
9. Left generator-transmission and voltage regulator control check OK; distribution system faulty
10. Distribution system checks OK; left generator-transmission or voltage regulator control faulty
11. Right generator-transmission and voltage regulator control check OK; distribution system faulty
12. Distribution system checks OK; right generator-transmission or voltage regulator control faulty

If the left engine were started first, all power would be supplied by the left main generator to the left and right main power buses via the LMC and RMC contactors. The external connector may be removed and the right engine started. When this occurs, the RMC contactor will transfer, allowing the right generator to feed the right main buses. In the event of an engine or a-c generator failure, automatic transfer of the affected a-c bus to the operating generator will occur. All essential buses are normally fed by the left main buses. An alternate source is the hydraulically driven emergency generator which is enabled when multiple engine, main generator, or transformer rectifier failures occur. Because the emergency generator cannot supply sufficient power to drive all aircraft loads, its application is restricted to the essential loads which, in turn, are fed by the essential buses. Depending upon the failure mode the emergency generator will supply power to

- All essential a-c and d-c buses
- Essential 1 a-c and 1 d-c buses.

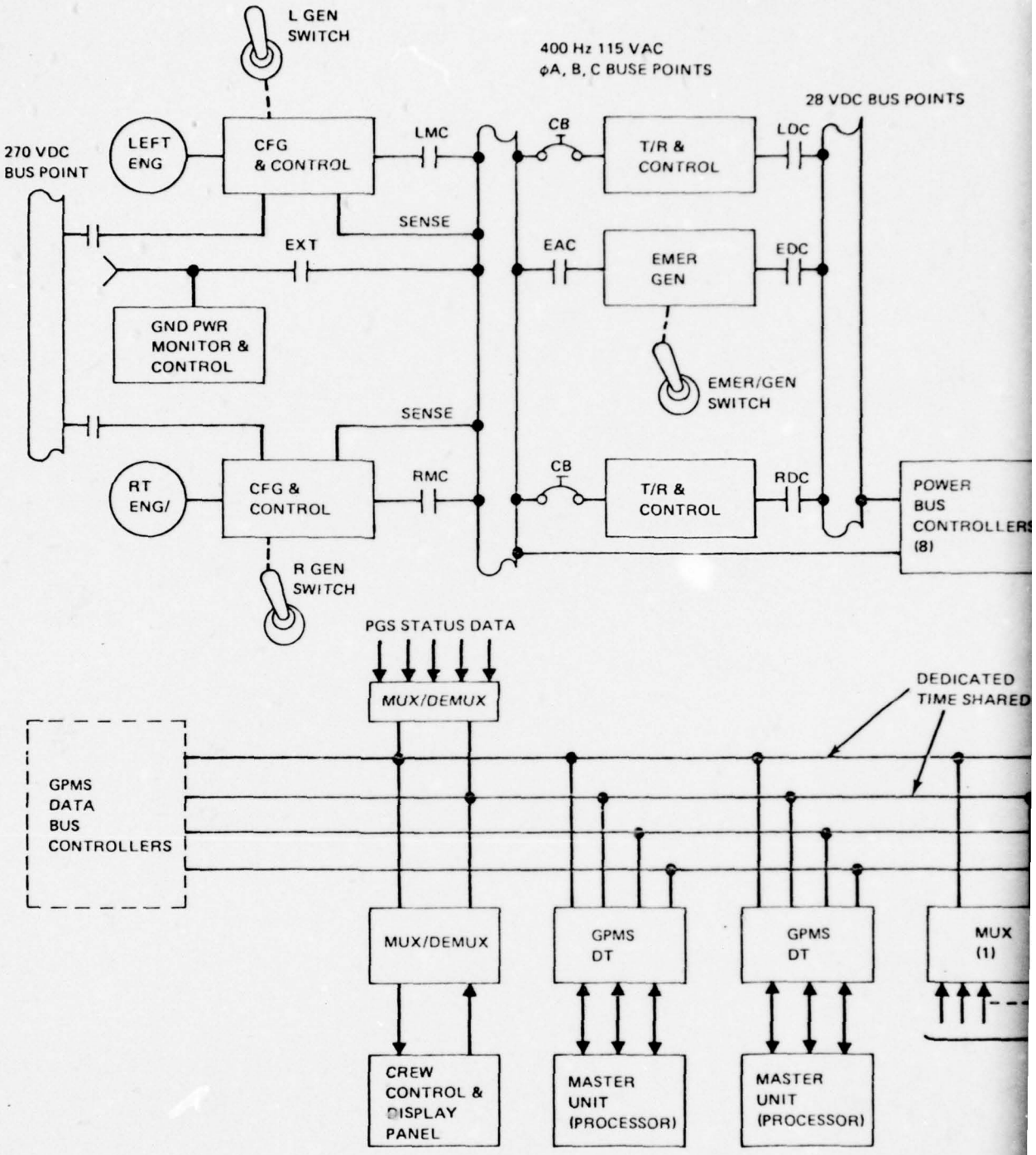
The transformer rectifiers normally feed their respective buses via a bootstraped configuration of their contactors. In the event of a transformer rectifier failure, its contactor is de-energized and relaxes such that the failed side is supplied power by the operating transformer rectifier. Diode coupling provides isolation and a power feed path from the main d-c buses to the interruption-free bus. This bus supplies power to those loads which would be highly susceptable to 28 vdc interruptions. Circuit breaker protection is provided to isolate failures of a transformer rectifier from the main a-c buses. No form of protection is available for an a-c bus short which cannot be cleared by the main generators. The pilot has the option of removing a main generator from the line or disabling the emergency generator by placing the respective switch in the OFF/RESET position. This position also resets any triggered detection circuits in the

respective control unit. The TEST position will also remove a main generator from the line. This is the extent of an operator's control over the operation of the PGS system.

3.2 PROTOTYPE AAES CONFIGURATION

A baseline prototype AAES (Fig. 3-2) was derived utilizing the present F-14 aircraft and the AAES requirements. The system is applicable to any two-engine, high-performance aircraft. Certain basic ground rules were established which are consistent with the requirements and are discussed below:

- Constant frequency generator (CFG) - d-c link machines capable of operating in a synchronized parallel mode will provide 270-vdc and primary 400-Hz, 115-vac power. Separate transformer rectifiers will be utilized to provide 28 vdc power similar to the present F-14 system.
- The majority of power-user equipments (subsystem WRA's) will not be re-designed to accept 270 vdc. Until a detailed study is performed evaluating the advantages and costs of converting the present WRA's and ground support equipment to 270-vdc users, it will be assumed that the majority of AAES user equipments will require the same power form and quality as on the present F-14 aircraft. The SOSTEL control group equipments can have 270-vdc power inputs as well as 115 vac. The 270-vdc power is available for what is expected to be a limited demonstration by user WRA's and simulated loads.
- The main bus points (output of the contactors) do not short. This assumption is consistant with the philosophy and design of the present F-14 aircraft. The buses are not considered susceptable to shorts which cannot be cleared by the generating equipment. If bus short protection were provided the system would require a split synchronized configuration capable of being paralled by bus tie contactors. In addition, manual and automatic control of the bus tie contactors would be required, as well as bus fault sensing circuitry. Further more, this


L GEN SWITCH
400 Hz 115 VAC
φA, B, C BUSE POINTS
28 VDC BUS POINTS
270 VDC BUS POINT
LEFT ENG
CFG & CONTROL
LMC
CB
T/R & CONTROL
LDC
SENSE
EXT
EAC
EMER GEN
EDC
GND PWR MONITOR & CONTROL
EMER/GEN SWITCH
SENSE
RT ENG/
CFG & CONTROL
RMC
CB
T/R & CONTROL
RDC
POWER BUS CONTROLLERS (8)
R GEN SWITCH
PGS STATUS DATA
MUX/DEMUX
DEDICATED
TIME SHARED
GPMS DATA BUS CONTROLLERS
MUX/DEMUX
GPMS DT
GPMS DT
MUX (1)
CREW CONTROL & DISPLAY PANEL
MASTER UNIT (PROCESSOR)
MASTER UNIT (PROCESSOR)

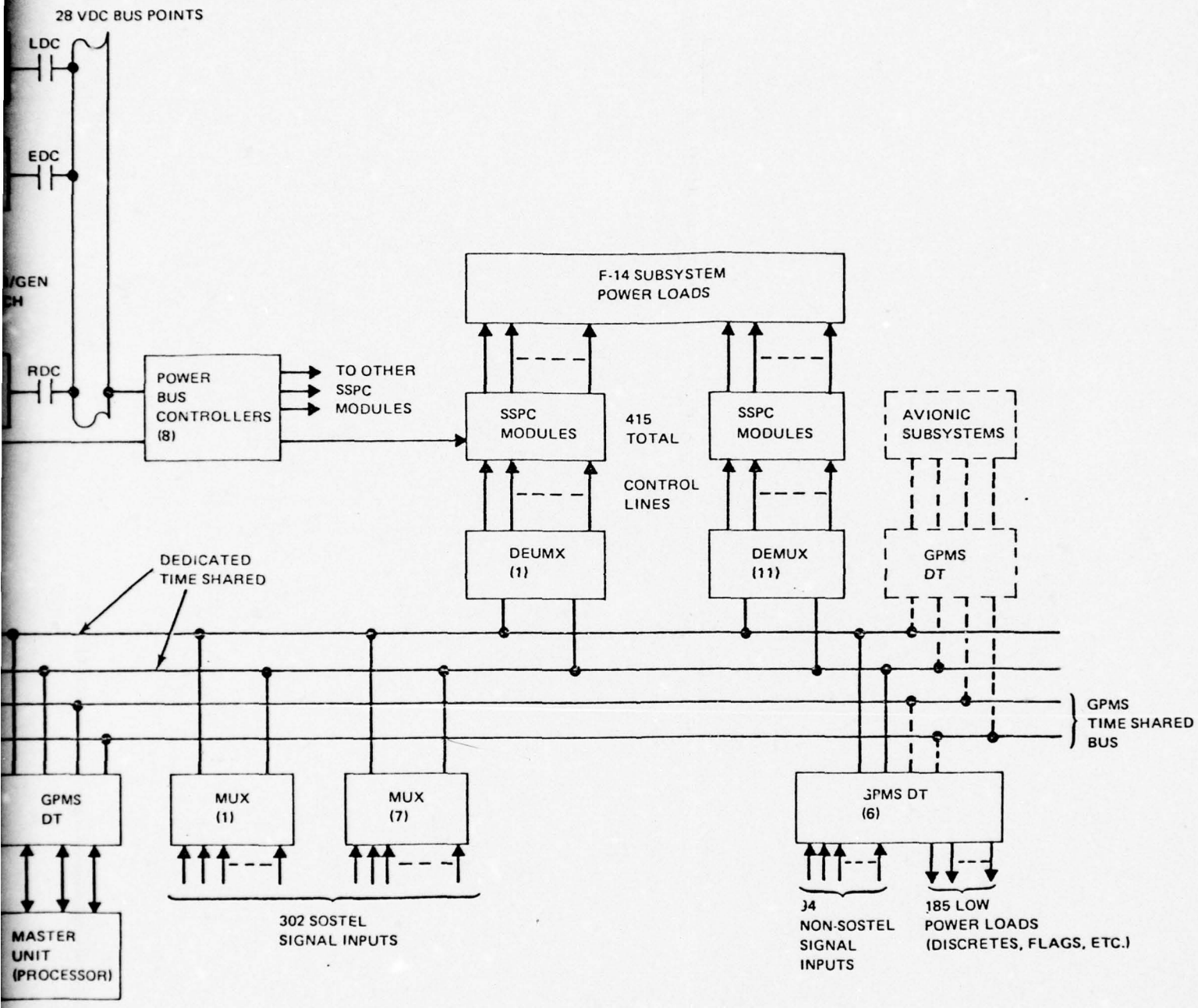


Figure 3-2. Prototype AAES System

would require a distribution system (SOSTEL) which, as a minimum, is dual system redundant and oriented about the bus architecture.

- The SOSTEL system will contain GPMS data terminals having I/O's capable of driving low power loads (discretes, lamps, flags, etc). In addition, these terminals will be capable of sampling non-SOSTEL signal sources (Open/gnd, 28v/gnd, etc). These GPMS data terminals may service other subsystem functions as well as SOSTEL. Those uniquely servicing SOSTEL will operate as a "MUX" or "DEMUX" in a command/response mode. Those servicing other subsystems as well as SOSTEL will operate in a polling mode. No attempt was made during this study to specifically define the additional subsystems which may also be serviced by GPMS. Communication between SOSTEL and other GPMS systems will be performed via the master units in a polling mode.

- The SOSTEL system will perform load management at the solid state power controller level. This is required to provide the software equivalent of the present F-14 essential buses during emergency modes. This implies that the SOSTEL system will monitor the PGS configuration and contain nonvolatile memory. A description of the SOSTEL operation for load management is described in Subsection 4.2.2, PGS/SOSTEL Monitoring and Load Management.

- The installation of the SOSTEL elements was based upon not removing or modifying the present installation of subsystem WRA's, except those that could be deleted by the use of the SOSTEL system. This required, in most cases, that the SOSTEL equipments be installed in locations having a limited height profile. This restraint would not be so severe in new aircraft or in a flight test aircraft.

- Critical aircraft subsystems require redundant SOSTEL functions and equipments.

This study did not identify the detail redundancy requirements. It is expected that the detail design of the prototype aircraft will do so. However, it did identify certain areas where a single thread system is not adequate. Typical of these are the following:

- Requirement for Multiple Transducers Sampled by Different Multiplexers - Typical of this function is the Weight on Wheels (WOW) interlocks. This term is used in approximately 100 of the equations tabulated.
- Separate Processor Boolean Solutions for the Same Equation - The roll and pitch computer utilize the same equation form for the ground roll braking signals but require separate paths. The SOSTEL equivalent is a separate solution and driver.
- Redundant SSPC's for Flight Critical Loads Driven by Separate Demultiplex Terminals - An example of this is those avionic boxes which have multiple circuit breakers. The yaw computer is typical, it has three power supplies (A, B and M) each requiring 115 vac (ØA and ØB), and 28 vdc. Each power supply should be driven by a separate controller whose control line eminates from a different DEMUX terminal.

The major elements of the prototype PGS configuration are as follows:

- Constant Frequency Generators (CFG) (2) - The characteristics of this generator are described in detail in Subsection 4.1.1. Each CFG is capable of supporting the entire load requirements of the F-14 aircraft. The significant characteristics of each CFG are summarized below:
  - The CFG will provide a 75-kva output at all power factors from 0.75 lagging to 1.0 and all electrical characteristics will conform to MIL-E-23001A (AS)
  - One oil-cooled package consisting of the following major sections:

- o Integral gear box mounted directly to the engine pad with input speeds of 3700 to 7400 rpm
- o Conventional conduction-cooled, wild-frequency generator operating over a speed range of 7,500 to 15,000 rpm with its output rectified and changed to high voltage
- o D-C link converter providing high quality 3-phase, 400-Hz, 115-vac
- o Generator control unit
- o Voltage regulator

- The CFG will be installed in place of the present IDG and will be cooled via the IDG cooling loop providing oil coolant to the CFG at 185°F maximum temperature.
- Electrical and oil connections will be similar to the present installation.
- The CFG will use the present weight of an IDG (115 lb) or less as the design goal.

- Left main a-c power contactor (LMC) (1)
- Right main a-c power contactor (RMC) (1)
- External a-c power contactor (EXT) (1)

These contactors are identical to the power contactors K1, K2, and K3 utilized on the present F-14 aircraft and are located in the a-c power contactor assembly (66A6).

- Ground Power Monitor and Control (1) - This unit is identical to the present ground power monitor and control assembly (66A3).
- Transformer Rectifier and Control (2) - These units are similar to the present 100-ampere, 28-vdc transformer rectifiers. However, the output contactors will contain reverse-current sensing control circuitry to provide reverse

current protection in the event of a transformer rectifier output failure during parallel operation. Each transformer rectifier must be capable of supporting the entire F-14 d-c load requirements.

- Emergency A-C (EAC) and D-C Contactors (EDC) - are identical to the a-c and d-c essential contactors located in the a-c power switching assembly (67A2) and d-c power switching assembly (67A3)

- Emergency Generator And Control (1) - The units are similar to the present motor generator (67G1) and its control unit (67A1). The generator is a hydraulicly driven unit capable of providing 5 kva, 115/200 vac and 50 amperes, 28 vdc. This generator can supply sufficient power to support the F-14A aircraft a-c and d-c essential loads.

- Bus Controllers - Remotely controlled circuit breakers (8) capable of suppling power to banks of solid state power controllers will be centrally located close to the main bus points and provide isolation between the buses and the solid state power controllers.

The major elements of the prototype SOSTEL distribution system are defined by the following documents which were used as a guide in the development of the system.

a) MIL-P-81653A - "Power Controller, Solid State, General Specification for"

b) MIL-P-81653/6A - "Power Controller, AC Bus Switching, SPST, Normal Open, 10 Amperes"

c) MIL-P-81653/7A - "Power Controller, AC Bus Switching, SPST, Normal Open, 75 Amperes"

d) MIL-S-81619B - "Switches, Solid State Tranducer, General Specification for"

e) NADC Technical Memo No. VT-TM-1791 - "BIT for SOSTEL III Components", of 17 Oct 1974

f) NADC Technical Memo No. VT-TM-1790 - "Aircraft System Function Designation Letters, Selection Guide for" of 16 Oct 1974

g) MIL-P-81653/2A - "Power Controller, Solid State, SPST, Normal Open, 2 thru 10 Amperes"

h) MIL-P-81653/3A - "Power Controller, DC Load Switching, SPST, Normally Open, 15 thru 35 Amperes"

i) MIL-P-81653/4A - "Power Controller, AC Load Switching, SPST, Normal Open, 2 thru 10 Amperes"

j) MIL-P-81653/5A - "Power Controller, AC Load Switching, SPST, Normal Open, 15 thru 35 Amperes"

k) MIL-C-81833 (AS) - "Control Group, Electric Power, OK-171, General Specification for"

l) NADC-VT-TS-7301/1A - "Control Group, Electric Power, OK-171, Detail Specification for"

m) Spec NADC 203-1 of May 1973 - "Specification for a General Purpose Multiplex System AN/UCC ( ) XJ"

The prototype SOSTEL distribution system contains the following major elements:

- Data Bus Channels (4), Stubs, Terminations

  One dedicated and one time shared channel are considered adequate for SOSTEL use.

- Master Units (2)

  The master units contain the SOSTEL processors.

- Multiplexers (7)

  Providing interface to solid state transducers or switched impedance circuits.

- Demultiplexers (11)

  Providing interfaces to solid state power controllers.

- Multiplexer/Demultiplexer (2)

  Interface to the CCDP and PGS

- GPMS Data Terminals (8)

  Six of these units contain user I/O's compatible with non-SOSTEL transducers and capable of driving low power loads (flags, discretes etc). Two units provide an interface for the SOSTEL MU.

- Crew Control and Display Panel or Pilots Panel (1)

- Solid State Power Controller (366)

  - 28 vdc, 2 a (116)
  - 28 vdc, 5 a (39)
  - 28 vdc, 10 a (23)
  - 115 vac, 2 a (176)
  - 115 vac, 5 a (12)

- Hybrid Relay Controllers (47)

  115 vac, 10 a (47)

- Remotely Controlled Circuit Breakers (2)

  115 vac, 50 a (2)

- Signal Transducers/Sources (396)

  Solid state (185)

  Switched impedance (117)

  GPMS (94)

3.3 PROTOTYPE AAES OPERATION

The operation of the prototype AAES can best be illustrated by the operation of the contactors and their associated control circuitry.

3.3.1 Power Generation Subsystem (PGS)

- External Contactor (EXT) - The EXT contactor is controlled by its associated ground power monitor and control unit. The EXT contractor provides a means to supply ground power to the a-c buses during ground operations and startup. The control unit is capable of determining the quality of the external power and closing the EXT contactor to energize the main a-c buses. The present F-14 configuration disconnects ground power from the main buses whenever the left main generator comes on line. Minor wiring modifications routing the ground power control line through auxiliary contacts of the left and right main contactors (LMC and RMC) will disconnect ground power when either main generator comes on line. A reset capability is provided to reset the ground power control circuitry in the event of a trip out due to poor quality ground power.

- Left Main A-C Contactor (LMC) or Right Main A-C Contactor (RMC) - The LMC and RMC are controlled by their respective CFG control units. These units sense the following inputs to determine the state of the LMC and RMC:

  (a) The output of the generators to determine power quality. The generator outputs are typically monitored for voltage, frequency, phasing and current characteristics by detector circuits. A complete listing of a typical (Bendix) CFG quality/operating parameters that control the contactors is tabulated along with other system parameters in Section 4.

  (b) The state of the bus for dead bus sensing

  (c) The output characteristics of the opposite generator for synchronization

  (d) The engine speed

In addition, the control units will interface to their respective three-position cockpit switches. The switches are usually in the NORMAL position; in this position, the respective contactor is closed if the generator output characteristics are satisfactory. The OFF/RESET position disconnects the contactors from the bus and resets the control unit detector circuits. In the TEST position the generator is allowed to operate normally, but the contactor opens, thus isolating the outputs from the bus. The state of the power generation system can be monitored by as few as three caution and warning lights (left and right generators, and transformer rectifiers) similar to the present F-14 caution and warning display. However, it is anticipated that a production aircraft will contain an integrated display system similar to the Advanced Integrated Modular Instrumentation System (AIMIS) master monitor display, which will provide the PGS display requirements. The crew control and display configurations illustrated in Subsection 4.2.4 are considered interim units primarily associated with SOSTEL laboratory, and near-term flight checkout.

- Left Main D-C Contactor (LDC) or Right Main D-C Contactor (RDC) - The LDC or RDC contactors provide a power path to the 28-vdc bus from the transformer rectifiers. Contactor control circuitry will be designed to sense reverse current and disconnect the contactor from the bus in the event of a transformer rectifier failure.

- A-C and D-C Emergency Contactors (EAC) (EDC) - The EAC and EDC contactors provide a means of energizing the a-c and/or d-c buses in the event of loss of both main CFG's or both transformer rectifiers. The generator will come on line approximately 1 second after loss of main d-c power. Main d-c power is utilized to hold the hydraulic solenoid valve closed. Control circuitry will

prevent motorboating of the valve once main d-c power is lost. This can be performed by interlocking the control valve drive with auxiliary contacts of the main contactors. Loss of main a-c power (LMC and RMC contactors open) will cause the EAC and EDC contactors to close. Loss of main d-c power will cause only the EDC contactors to close. Insufficient emergency power to support all essential loads which would normally cause the essential 2 bus to be de-energized in the present F-14 aircraft emergency mode and will provide information for SOSTEL load management. A detailed description of the load management options utilizing SOSTEL load shedding techniques is described in Subsection 4.2.2.

Table 3-2 illustrates the major PGS configurations as a function of a varity of system equipment failures. The SOSTEL load priorities relate to the loads which will be enabled during emergency generator operation and are further defined in Subsection 4.2.2. Normal operation (PGS mode 4) will be maintained provided one engine/generator and one transformer rectifier are operating.

3.3.2 SOSTEL

- Bus Controllers/Power Controllers - Six bus controllers (100-ampere, remote-controlled circuit breakers) will be utilized to provide isolation and feed banks of solid state power controllers operating off the 3-phase a-c bus points. These bus points are the output of the LMC, RMC and EXT contactors. Two bus controllers (75-ampere, remote-controlled circuit breaker) will provide isolation and feed banks of d-c power controllers. The bus controllers are necessary to protect the bus from shorts which may occur on the input power lines of the solid state power controllers. Shorts between the power controllers and the loads are isolated by the trip-out action of the power controllers. The 415 power controllers were identified and installed on modules located as physically close to the loads as possible. Approximately 70% of the SSPC's are 2-ampere, 28 vdc and 115-vac devices.

TABLE 3-2. MAJOR PROTOTYPE AAES CONFIGURATIONS

CONDITION	L GEN SWITCH	R GEN SWITCH	EMERG SWITCH	EXT POWER	ENGINES L	ENGINES R	EMERG GEN	CPG L	CPG R	TR L	TR R	EXT	LAC	RAC	LDC	RDC	EAC	EDC	306TEL LOAD MODE	306TEL LOAD PRIORITIES
1	NORM	NORM	NORM	ON	THOT	THOT	THOT	THOT	THOT	OP	OP	CLOSED	OPEN	OPEN	CLOSED	CLOSED	OPEN	OPEN	4	1, 2, 3
2	NORM	NORM	NORM	OFF	OP	OP	THOT	OP	OP	OP	OP	OPEN	CLOSED	CLOSED	CLOSED	CLOSED	OPEN	OPEN		1, 2, 3,
3	NORM	NORM	NORM	OFF	THOT	OP	THOT	THOT	OP	OP	OP	OPEN	OPEN	CLOSED	CLOSED	CLOSED	OPEN	OPEN	4	1, 2, 3,
4	NORM	NORM	NORM	OFF	OP	THOT	THOT	OP	THOT	OP	OP	OPEN	CLOSED	OPEN	CLOSED	CLOSED	OPEN	OPEN	4	1, 2, 3,
5	NORM	NORM	NORM	OFF	OP	OP	THOT	OP	OP	THOT	OP	OPEN	CLOSED	CLOSED	OPEN	CLOSED	OPEN	OPEN	4	1, 2, 3,
6	NORM	NORM	NORM	OFF	OP	OP	THOT	OP	OP	OP	THOT	OPEN	CLOSED	CLOSED	CLOSED	OPEN	OPEN	OPEN	4	1, 2, 3,
7	NORM	NORM	NORM	OFF	at least 1 engine OP		OP	Both CPG,s inoperative		THOT	THOT	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	2	1, 2 AC/DC
8	NORM	NORM	NORM	OFF	Both Engines fail		OP	THOT	THOT	THOT	THOT	OPEN	OPEN	OPEN	OPEN	OPEN	CLOSED	CLOSED	1	1, AC/DC
9	NORM	NORM	NORM	OFF	OP	OP	OP	OP	OP	THOT	THOT	OPEN	CLOSED	CLOSED	OPEN	OPEN	OPEN	CLOSED	3	1, 2 DC
10	NORM	NORM	NORM	OFF	OP	OP	THOT	THOT	OP	OP	THOT	OPEN	OPEN	CLOSED	CLOSED	OPEN	OPEN	OPEN	4	1, 2, 3,

CONDITIONS:

1. External electrical power on; engines not operating
2. Normal flight configuration
3. Left engine fail or left main generator fail
4. Right engine fail or right main generator fail
5. Left transformer rectifier failure
6. Right transformer rectifier failure
7. Both main generators fail, at least 1 engine operative, 306TEL sheds all priority 3 AC/DC loads, maintains priority 1 & 2 loads as long as hydraulic pressure available
8. Both engines fail, 306TEL sheds all priority 3 AC/DC loads, no hydraulic pressure drops sheds priority 2 AC/DC loads. If windmilling engines cannot provide sufficient hydraulic pressure to maintain emergency generator operation all power is lost
9. Both transformer rectifiers fail, 306TEL sheds all priority 3 AC/DC
10. One generator fails and one transformer rectifier fail.

- Transducers (Signal Sources) - Three hundred and ninty-six transducers or signal sources provide the control data information required by the SOSTEL master units for the solution of the Boolean equations. One hundred and eighty-five of these signals signals sources are solid state devices; 117 utilize the switched impedance concept, requiring add-on resistors to existing mechanical switches; and 94 cannot readily be adapted to either of the foregoing configurations, but must be sampled "as is" via GPMS data terminals.

- SOSTEL System (Control Group) - The prototype SOSTEL control group system follows the general operational guidelines identified in the NADC SOSTEL documents MIL-C-81833 (AS) and NADC-VT-TS-7301/1A. The system samples transducer information via the multiplexer terminals, and transmits this information to the master units which use it to solve their repertoire of Boolean equations. The resulting solutions are transmitted to the demultiplexer terminals which control the operation of the power controllers. GPMS data terminals containing suitable I/O's are included in the SOSTEL system to interface with input and output signals not adaptable to the standard SOSTEL system. The operational requirements of the various components of the SOSTEL control group are discussed in detail in the SOSTEL section of this report.

3.4 MINIMUM FLIGHT TEST AAES CONFIGURATIONS

Two minimum flight test configurations of the AAES system are illustrated in Fig. 3-3 and 3-4. These systems are designed about the present F-14A PGS configuration with the addition of a CFG or a HVDC/PCU primary power source. A 270-volt d-c bus, a bus tie (BT) contactor, bus controllers, solid state power controllers, and SOSTEL control group equipments are also included. These configurations evolved to provide a near-term flight demonstration of the AAES system without incurring the expense of the full prototype AAES configuration. The advantages of these configurations are:

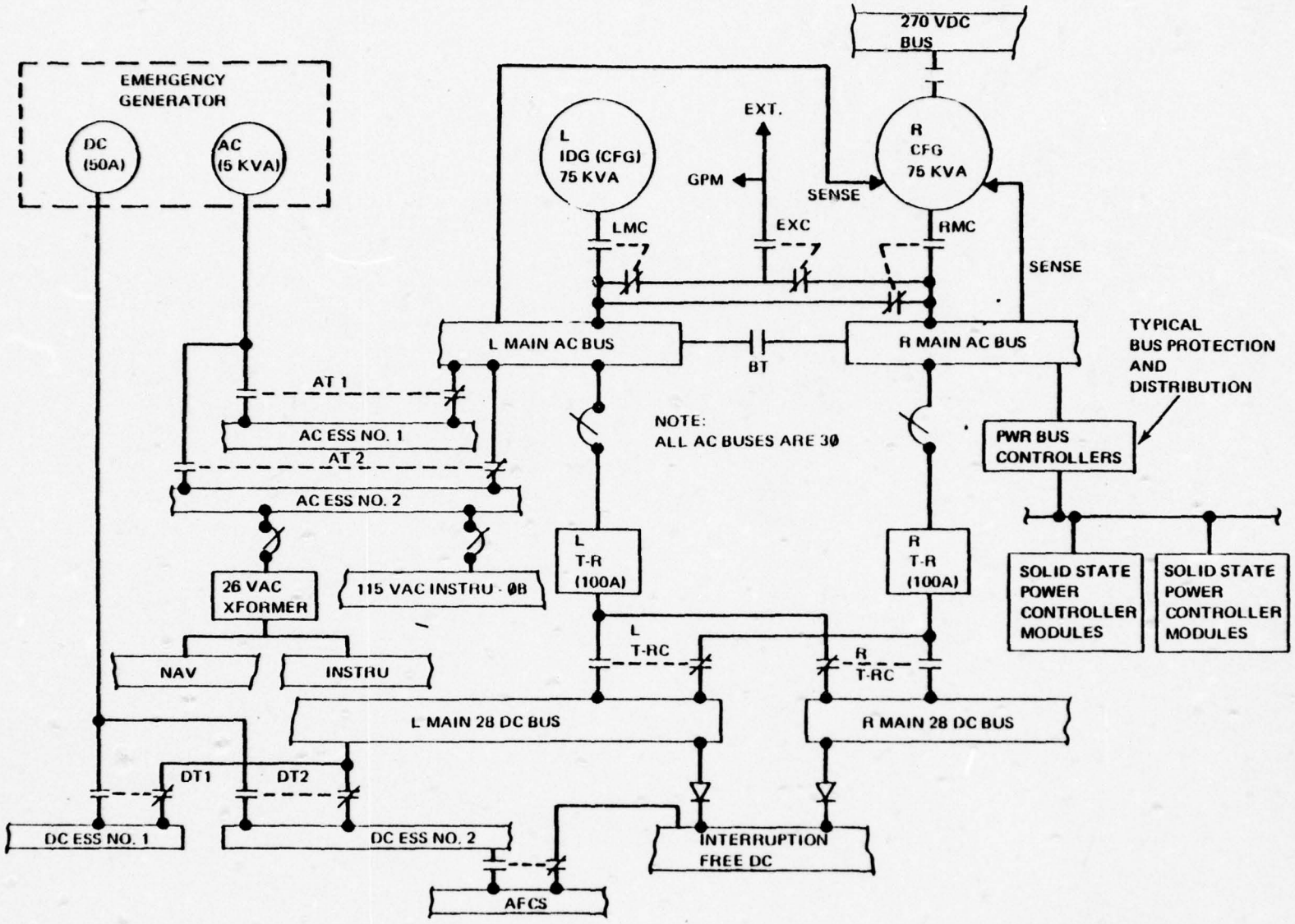


Figure 3-3. F-14A Power Distribution for AAES Minimum Flight Test Configuration - CFG

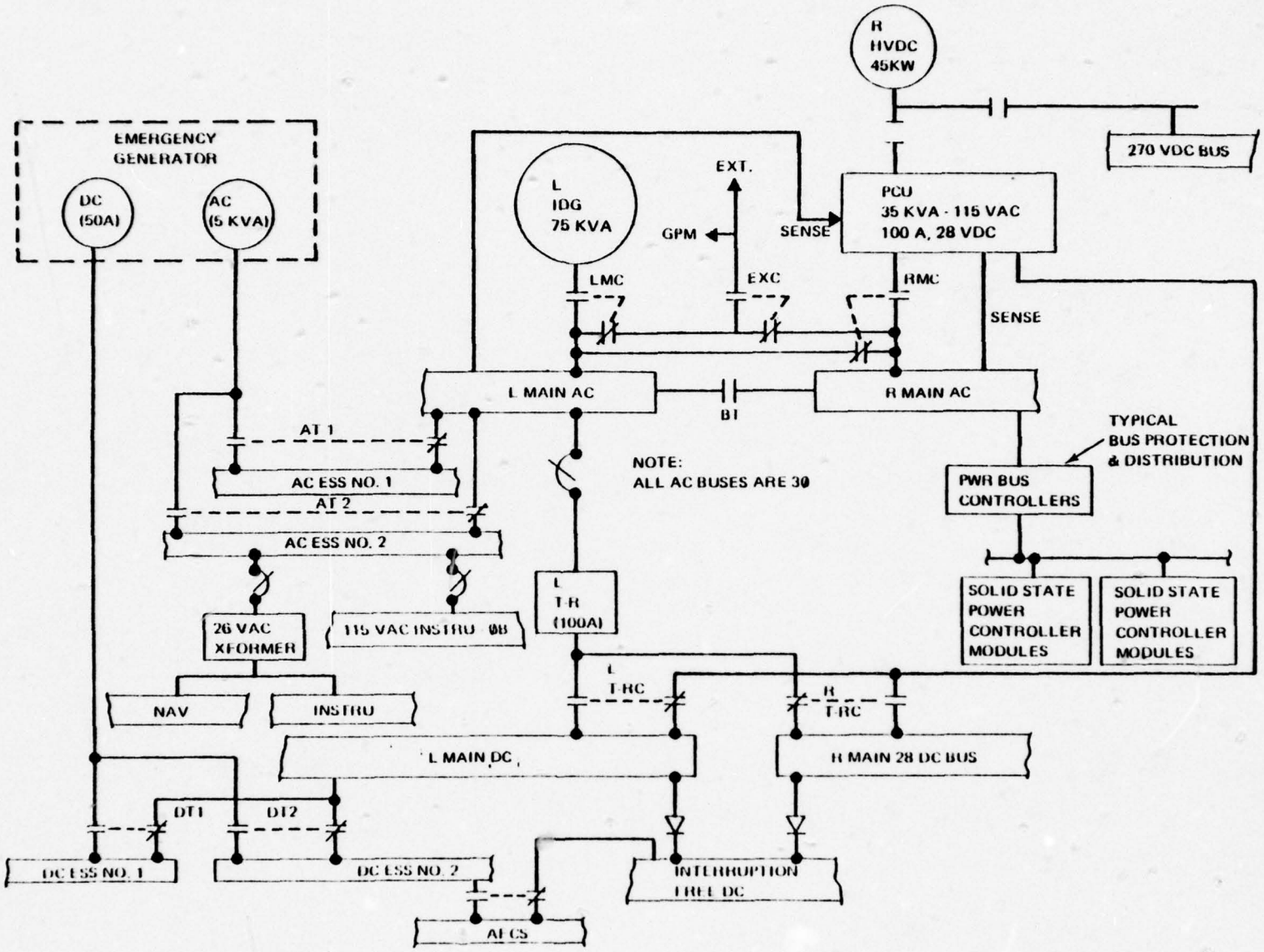


Figure 3-4. F-14A Power Distribution for AAES Minimum Flight Test Configuration - HVDC/PCU

- Flight Safety - They allow the maintenance of the present flight proven PGS bus and contactor configurations. The right CFG or HVDC - d-c link generator will be backed up by a flight proven IDG on the left side. After initial flight tests provide confidence in the generation system, the left IDG can be replaced. The emergency generator and the associated essential buses and contactors on the left main buses will not be disturbed.

- AAES Requirements - They are capable of demonstrating, in essense, all AAES requirements for the full-up prototype AAES configuration. Split or parallel synchronized operation of the CFG generator can be demonstrated using a manually controlled bus tie contactor. Also, 270-vdc power switching can be demonstrated using dummy loads or a limited number of nonessential loads modified for 270-vdc power input. SOSTEL power switching and simulated essential load management can be demonstrated utilizing nonessential loads selected from the main left and right 115-vac and 28-vdc buses tabulated for the prototype design.

- Cost - The cost of implementing the prototype system will be substantially reduced. The cost of configuring the aircraft for AAES as well as the cost of reconfiguring the aircraft after tests are complete would be minimized. In addition, if the M61A1 20 MM automatic gun and its associated ammunition canister, or the Pheonix missile system were removed, sufficient room in a central location to install a limited number SOSTEL/GPMS components would be available. (It should be noted that F-14 test aircraft No. 3 does not contain the gun or missile equipment.) Centrally locating the SOSTEL equipment during flight test would decrease installation costs, and is not considered a serious drawback to flight test integrity relative to the necessary dispursed location of SOSTEL equipment in a production aircraft.

- Operation - The operation of these PGS systems would be similar to the present F-14A system. The right generator may be an integral CFG - d-c link unit whose primary output is 115 vac, 75 kva as illustrated in Fig. 3-2. An

alternate configuration will utilize a 45-kw HVDC generator and a separately packaged power condition unit providing 35 kva a-c and 100 amperes, 28 vdc. This unit is consistant with NAVY prototype HVDC development efforts, but does require additional air cooling lines to be installed. The application of external power would energize all 115-vac and 28-vdc buses. The 270-vdc bus would not be energized until the right engine is started. Since this bus will drive a limited number of dummy loads or a minimum number of preselected nonessential loads configured for 270-vdc operation, this is not considered a serious drawback. The left engine would be started first. The left IDG would then energize all 115-vac and 28-vdc buses, and ground power will be disconnected. When the right engine is started, automatic transfer will cause the right buses and the 270-vdc bus to be powered by the CFG or PCU. SOSTEL control and management functions will be limited and demonstrated on noncritical loads. This operation is discussed in Subsection 4.2.2. A manually controlled bus tie contactor will allow split synchronized or parallel operation of the generators. When configured with a separate PCU as illustrated in Fig. 3-4, automatic transfer and support of the entire aircraft loads to the PCU would be inhibited in the event of a IDG failure since this configuration cannot support the entire F-14A load. In this event, the emergency generator would provide power to the essential loads via the essential buses, the left main buses would be supported by the PCU. A limited number of SOSTEL control group components (consisting of two master units, four multiplexer terminals, four demultiplexer terminals, one MUX/DEMUX terminal, three GPMS data terminals (serving SOSTEL functions), and one crew control and display panel) are deemed adequate to demonstrate all of the control group requirements.

3.5 AAES LABORATORY SYSTEM

The objectives of the AAES laboratory system are to provide a

- Baseline to integrate the system and develop the flight test configuration
- Vehicle for evaluation of AAES components and the system operation
- Test bed for developing the system software and assessing alternate system configurations and operation
- Medium for evaluating the pilot/maintenance panel man-machine interface
- Vehicle for operational "hands on" use to train AAES personnel
- Vehicle for identifying and developing the next generation 270-vdc equipments
- Vehicle for evaluating system operation under various failure conditions.

The recommended configuration of the laboratory system is illustrated in Fig. 3-5. The equipment complement should be consistant with the minimum flight test configuration. It is not necessary to duplicate the aircraft system completely. Specifically, the F-14A aircraft power bus configuration can be largely eliminated as it is a proven operational configuration. The HVDC/PCU or CFG are required for system integration, even though their capability and interface can be adequately demonstrated during unit bench tests.

A summary of AAES equipment required is as follows:

- CFG - D-C link or (HVDC-PCU) (1)
- Cable controllers (4)

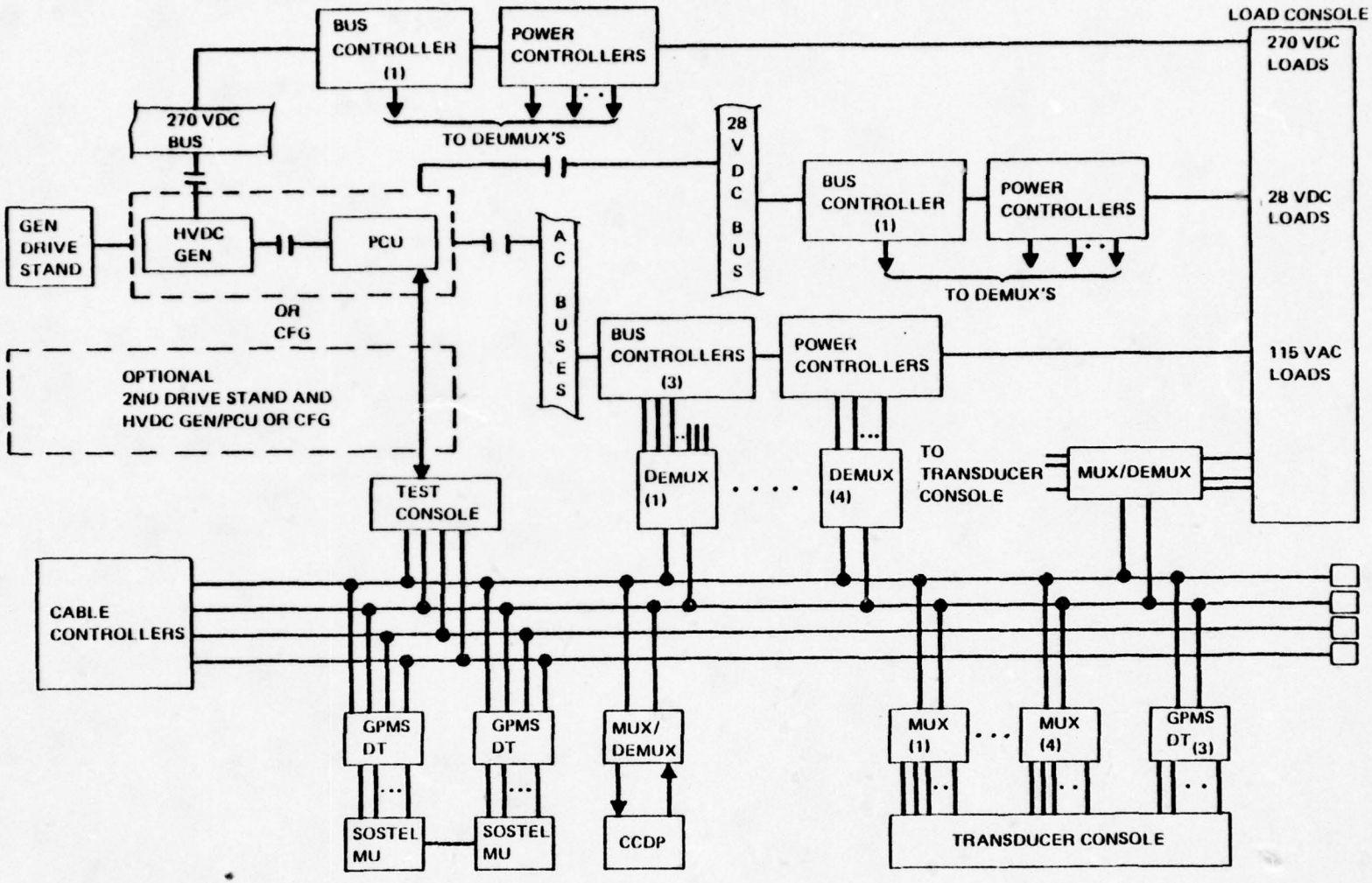


Figure 3-5. AAES Laboratory System

- Data bus channels, stubs, terminations, set (4)
- GPMS data terminals; (5)
- SOSTEL MU (2)
- CCDP or PP (1)
- MUX (4)
- DEMUX (4)
- MUX/DEMUX (2)
- Power bus controller - a-c (RCCB) (3)
- Power bus controller - d-c (RCCB) (1)
- Solid state power controller/hybrid controllers*
  - 28 vdc, 2 a (20)
  - 28 vdc, 5 a (10)
  - 28 vdc, 10 a (5)
  - 115 vac, 2 a (20)
  - 115 vac, 5 a (10)
  - *115 vac, 10 a (5)

  270 VDC, 2A (5)
- Solid state transducers
  - Pushbuttor lighted (16)
  - Pushbutton (16)
  - Toggle - SPST (16)
  - Toggle - SPDTCO (16)
  - Rotary - 10-position (8)
  - Limit (8)

- Switched impedance transducers
  - Toggle (SPST) (240).

A load console capable of providing simulated aircraft loads for 115-vac, 28-vdc and 270-vdc controllers is required. It should be able to introduce simulated fault and trip conditions. In addition this unit will provide simulated loads for low power signals driven by the GPMS terminals. A recommended mix is as follows:

- 115 VAC Loads
  - 2A (20)
  - 5A (10)
  - 10A (5)
- 28 VDC Loads
  - 2A (20)
  - 5A (10)
  - 10A (5)
- 270 VDC Loads
  - 2A (5)
- GPMS driven loads (Flags, Lights, Discretes, Relays)
  - 250 ma (32)
- DEMUX sink circuits* (245)

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* LED/switch circuits capable of displaying DEMUX output and simulating controller trip /fault conditions.

Section 4

PROTOTYPE SYSTEM DESIGN

4.1 POWER GENERATING SUBSYSTEM (PGS)

The AAES PGS study concentrated on the system evaluation and design integration of two competing (a-c or d-c) primary electric power sources. Primary emphasis was given to an a-c oriented PGS utilizing the variable speed constant frequency (VSCF) power generating concept. Within this area, two differing frequency changing and packaging designs were evaluated. One design (proposed by both the General Electric Company and the Westinghouse Electric Corporation) is comprised of a variable frequency generator and a solid state cycloconverter. The output of the generator is fed into a separately installed cycloconverter which changes the variable frequency power to constant 400 Hz, 3-phase power output. The other VSCF design (proposed by The Bendix Corporation and known as the Constant Frequency Generator (CFG)) takes a wild frequency input, converts this to dc and then chops the dc into square wave voltages and sums them in a transformer to produce a high quality sine wave output. This Bendix approach is also known as the DC Link Converter. The CFG - DC Link proposed for the prototype design consists of a generator, static converter, and control and protective circuitry housed in one oil-cooled package. Figure 4-1 illustrates the significant aspects of the competing a-c power sources.

A d-c oriented PGS utilizing high voltage direct current (HVDC) concepts having an output voltage of 270 $\pm$ 10 volts dc was studied for near-term F-14A flight test application. This approach requires conversion of the 270 vdc generator output to 115/208-volt, 3-phase, 400-Hz a-c power for selected utilization equipment (i.e., large electrohydraulic motors). It is felt that these brushless a-c machines could not be converted to brushless d-c operation by the early 1980's flight validation time frame planned for the AAES program. HVDC generator designs and parametric data

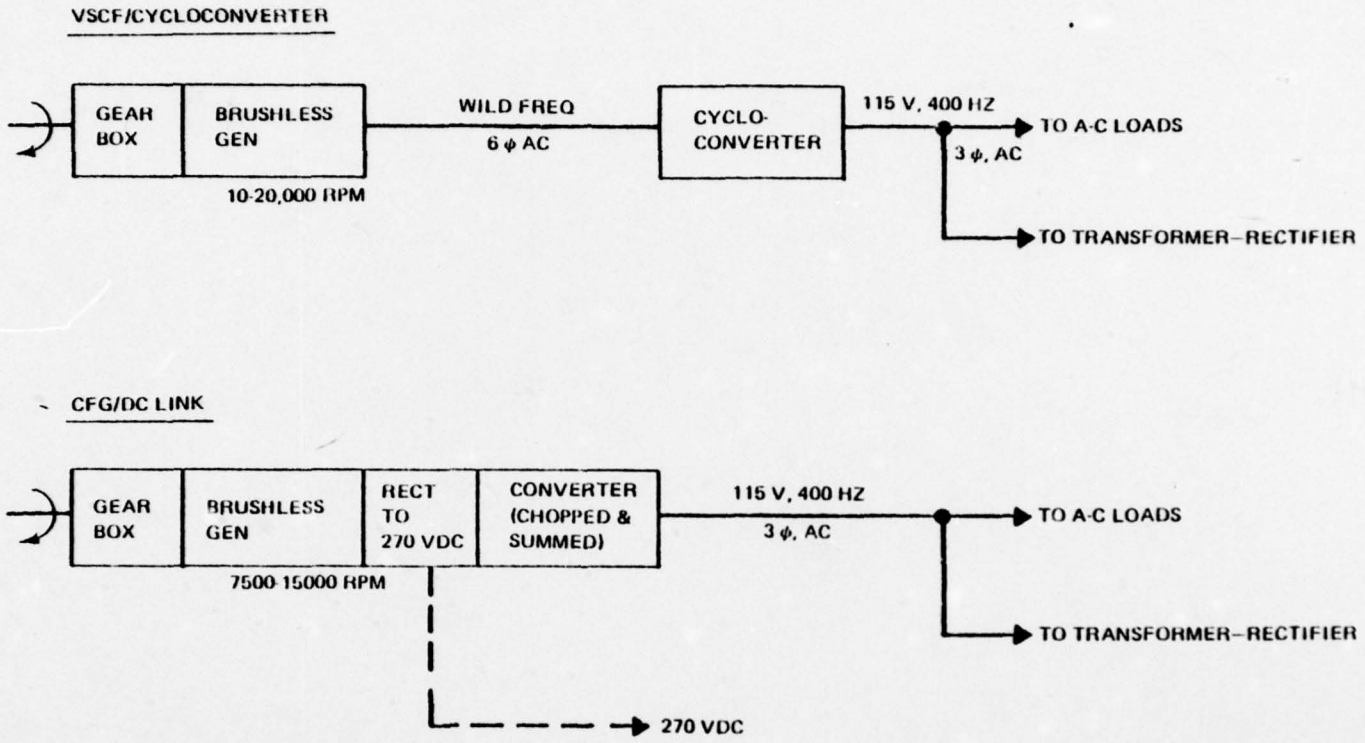


Figure 4-1. A-C Electric Power Generation/Conversion Alternates

for power conditioning units (PCU) were received from the Bendix, GE, Sundstrand and Westinghouse companies.

Early in the study, data packages defining the preliminary design and performance requirements for installing the VSCF/CFG and HVDC equipments in the F-14A aircraft were released to the appropriate potential suppliers. These data packages also described the technical data requested; when subsequently received, they were used to analyze and evaluate the competing concepts.

Candidate power distribution networks were developed ranging from the present multibus distribution system modified for parallel operation to a two-bus (one a-c and one d-c) system utilizing SOSTEL for complete load management. Eight a-c oriented configurations were evaluated for complexity, operational and SOSTEL control interfaces, and transformer-rectifier (TR) requirements.

The external and emergency electrical power systems presently on the F-14A were reviewed for compatibility with the a-c oriented PGS. In addition, the generation of secondary d-c power within the VSCF/CFG assembly versus the use of the present TR's was compared.

The present F-14A PGS control, monitoring, and operation were described and then used as the data base in developing the prototype AAES PGS for a future two-engine aircraft. The SOSTEL-PGS interfaces were examined and the recommended PGS parameters for SOSTEL application were identified.

A flight test configuration for near-term demonstration of the AAES PGS utilizing only the main buses of the F-14A plus maintaining the present flight proven bus and contactor configuration was developed.

4.1.1 VSCF/CFG Section

A significant effort was expended in generating the VSCF data package submitted to the suppliers, reviewing the responses and normalizing the data for evaluation comparisons and vehicle integration studies.

Installation constraints, service conditions, EMI control, cooling, and performance requirements were based on the present F-14A IDG specifications. System control, operational, and performance characteristics conform to MIL-E-23001A (AS) - "Electric Generating System, Variable Speed Constant Frequency, Aircraft, - General Specification For."

Seven companies were solicited for data, and responses were received from three: Bendix, GE and Westinghouse. The four other companies contacted (Delco Electronics, Lear-Siegler, Precise Power and Sundstrand) did not submit data.

The raw data received required "normalization" because of inconsistent interpretation of the requirements (e.g., engine pad input speeds). Functional descriptions of the competing designs are presented in the following sections; Table 4-1 illustrates the significant characteristics of each design.

4.1.1.1 Bendix

The constant frequency generating system would consist of the following parts assembled in one oil cooled package (designed to replace the present IDG system):

- Conventional conduction-cooled brushless a-c generator with a speed range of 7,770 to 15,540 rpm whose output is rectified to HVDC
- d-c link-type converter
- Generator control unit
- Voltage regulator
- Integral gear box with a 2.1 to 1 ratio.

Figure 4-2 is a cutaway drawing of the CFG's converter and generator and shows the mechanical construction planned for early versions. The CFG system block diagram is shown in Fig. 4-3.

TABLE 4-1. VSCF/CFG DESIGN CHARACTERISTICS

BASIC APPROACH	Bendix D-C-Link	G.E. Cycloconverter	Westinghouse Cycloconverter
Generator			
Phases		6	6
Nominal Voltage, L-N	(270VDC)	165	170
Frequency		1400 to 2800	1200 to 2400
Number of Poles		14	12
Speed Range, RPM	7800 to 15600	12000 to 24000	12000 to 24000
Step-Up Gear Box Reqd.	Yes	Yes	Yes
Cooling Oil Spray			
Oil Flow, GPM	3-10	6	4-5
Oil Inlet Temp, Max	185°F	300°F	300°F
Weight, lb	122	98.5	93
Overhung Moment, lb-in.	~1200	1175	870
Diameter, in.	12.2	9.5	8.5
Overall Length, in.	21.1	18.5	19.6
Efficiency at Rated Load (P.F. = 1.0)	82.3	82	82.1
Converter			
Weight, lb		69	71
Volume, Cu. in.		1680	2340
Size, in.		24 x 12 x 5.8	24 x 13 x 7.5
Eff at Rated Load	Included	Included in Gen.	94.6%
Coolant	In	Oil	Air
Max Coolant Inlet Temp	Generator	160°F	160°F
Channel			
Weight, lb	122	167.5	164
Combined Eff	82.8%	82%	77.5%
MTBF Estimate	3000 hr*	700 hr*	4400 hr**

NOTES:
*Grumman Estimate
**Westinghouse Estimate

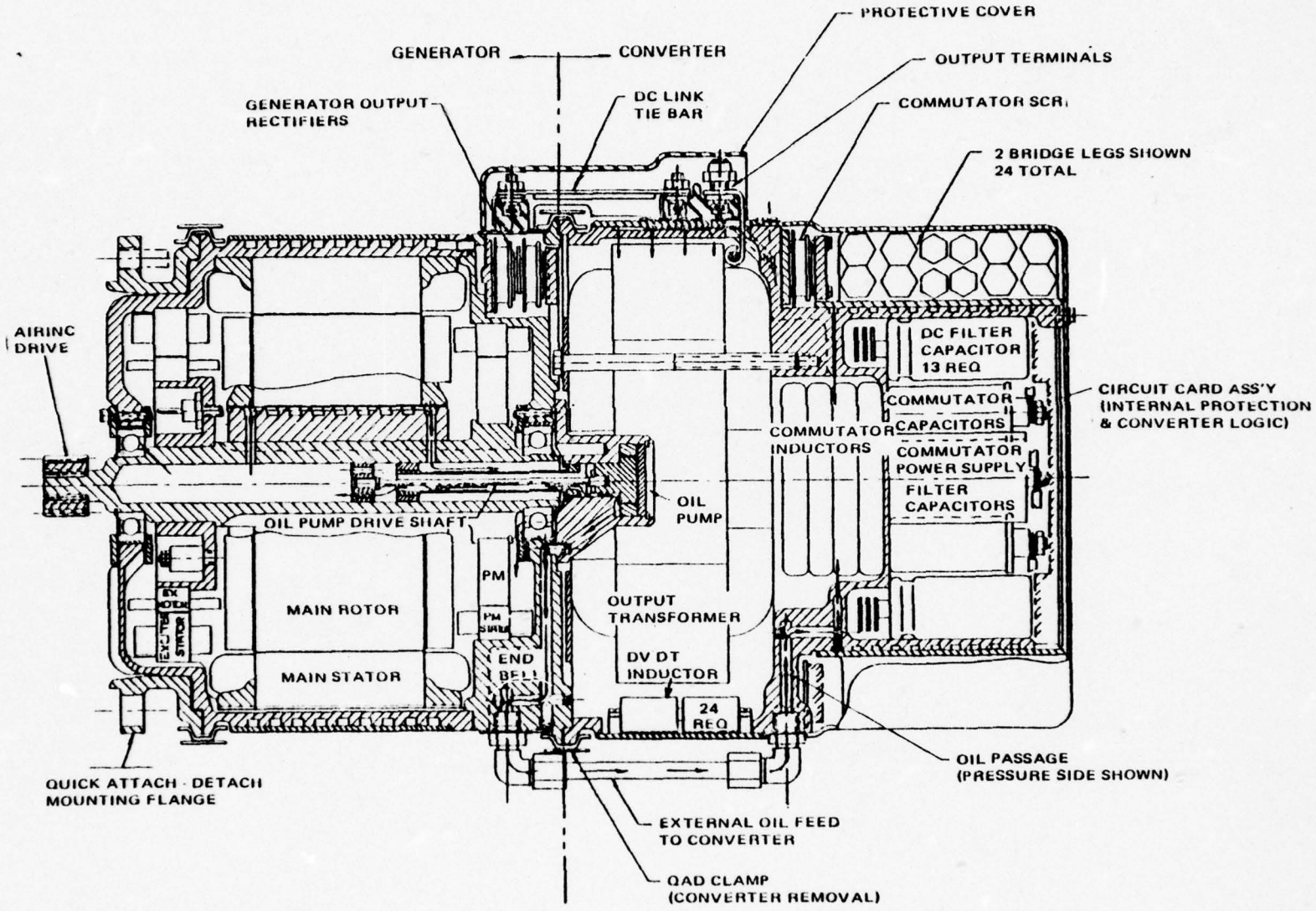


Figure 4-2 Bendix CFG Cutaway Drawing

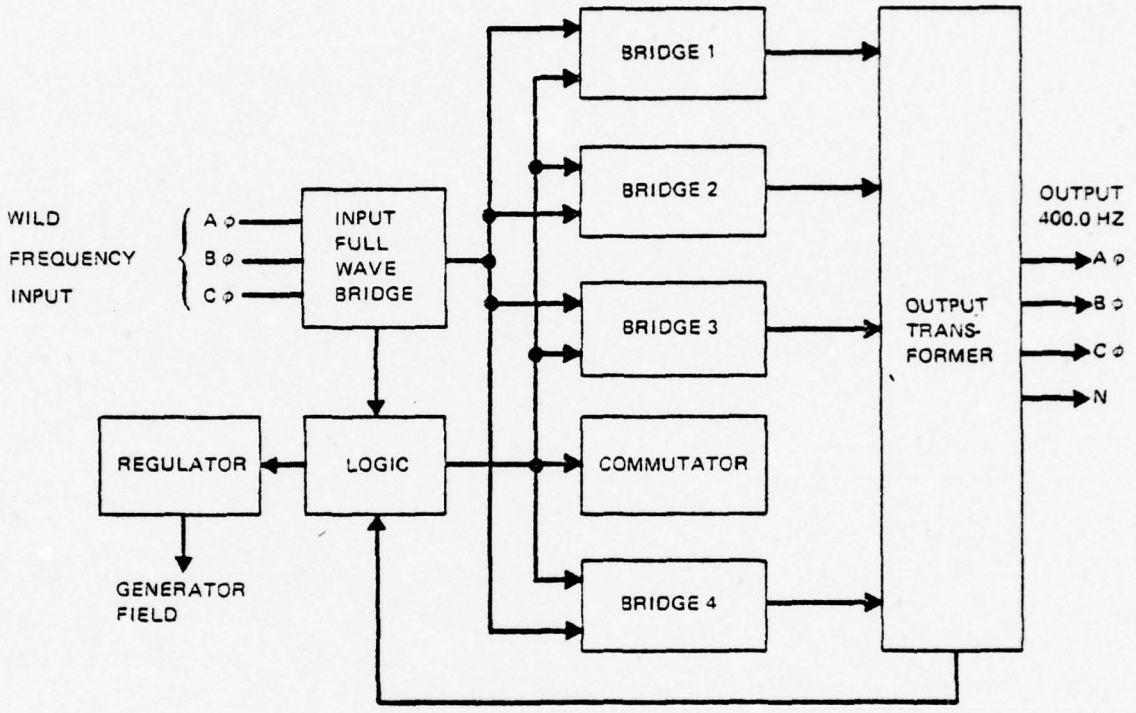


Figure 4-3. Bendix CFG System Block Diagram

The generator used in the CFG is a salient pole, synchronous machine incorporating a brushless ac exciter. A three phase, half-wave rectifier is used to provide d-c to the salient pole field. An oil cooling system provides cooling to the rotor and stator and lubrication and cooling for the bearing. The main generator stator and rotor, exciter stator and rotor, permanent magnet generator, and rotating rectifiers utilize materials and design techniques proven in various previous applications.

The proposed system for generating a constant frequency output is called a dc Link Converter. It gets its name from the fact that it takes a wild frequency input and converts this to d-c. The d-c is then chopped into square wave voltages and summed in a transformer to produce a high quality sine wave output.

The generator is the supply for the entire system. It produces the voltage to run the logic and control in addition to supplying the power for the converter output. The bruchless a-c generator's output is rectified by a full-wave, three-phase bridge to produce the d-c voltage required to run the system.

There are two converters operated from the d-c input to the converter section. The first is a d-c to d-c converter used to supply the logic and control power. The second is the d-c to a-c converter for the constant frequency output.

The d-c to d-c converter is designed to operate with an input voltage range of 30 to 300 volts dc, with a startup circuit designed to build up the generator from the residual voltage. The control power includes the commutator power supply, the generator voltage regulator power supply, the protective circuit power supply and the digital logic power supply.

The d-c to d-c converter is a square wave static converter with its output rectified by full wave bridges. It is a transistorized converter with a voltage regulated output.

The d-c to a-c power converter uses full-wave, three-phase SCR bridges as basic building blocks. The output of the bridges is summed in the output transformer.

The output transformer for this system has a unique 12-phase input and 3-phase output winding. Its primaries are four separate three phase inputs, two wyes and two deltas separated by 15 degrees. Because the core is symetrical and has four three-phase windings, all of the harmonics lower than the 23rd are cancelled in the core. This feature eliminates the necessity for bulky output series filtering as required by most converters.

The primary turns ratio is designed to yield a close approximation of a sine function. This has the result of balancing the input current to each bridge so that each SCR or diode is carrying the same amount of current.

The filtering capability of the transformer has other advantages also. First, it changes the input to each winding into a sine wave of current in spite of the square wave of voltage. It also has the advantage of filtering high frequency noise generated by switching transients from the load because they cannot be coupled through the transformer.

The voltage regulator for this system monitors both the generator terminal voltage and the output of the converter. This is done to improve the transient response of the system. The generator sensing prevents a large undershoot of the input voltage during load on transients, at which time the input capacitors used to filter the d-c bus can support some portion of the load current. The regulator has temperature compensation and stability networks to keep the output voltage within the specified limits.

The protective and control features of this system are listed in Table 4-2.

The proposed oil cooling loop within the CFG is shown in Fig. 4-4 and the system's operating efficiency and heat rejection requirements are illustrated in Fig. 4-5. The CFG has been designed to function with a maximum cooling oil input temperature of 185°F (85°C). Output temperatures are not expected to exceed 300°F (149°C). The critical temperature components are the SCR's and Bendix recommends rating this component for continuous duty at 212°F (100°C) case

TABLE 4-2. PROTECTIVE AND CONTROL FEATURES

Feature	Benlik	G.E.	Westing-house
Generator field control and Indication	X		
Generator circuit breaker control	X	X	X
Bus tie Breaker Control	X		
Auto-Parallel	X		
Auto-Parallel by-pass	X		
Underspeed protection	X	X	X
Overvoltage and Overexcitation protection	X	X	X
Undervoltage and Underexcitation protection	X	X	X
Underfrequency protection	X	X	X
Overfrequency protection	X	X	X
Difference current protection	X	X	X
Real Current Sensing	X		
Generator Overvoltage protection	X	X	X
Differential current protection	X	X	
Overcurrent protection	X	X	
Voltage regulator	X	X	X
Transient suppressor	X		
Extraneous Frequency Content		X	X

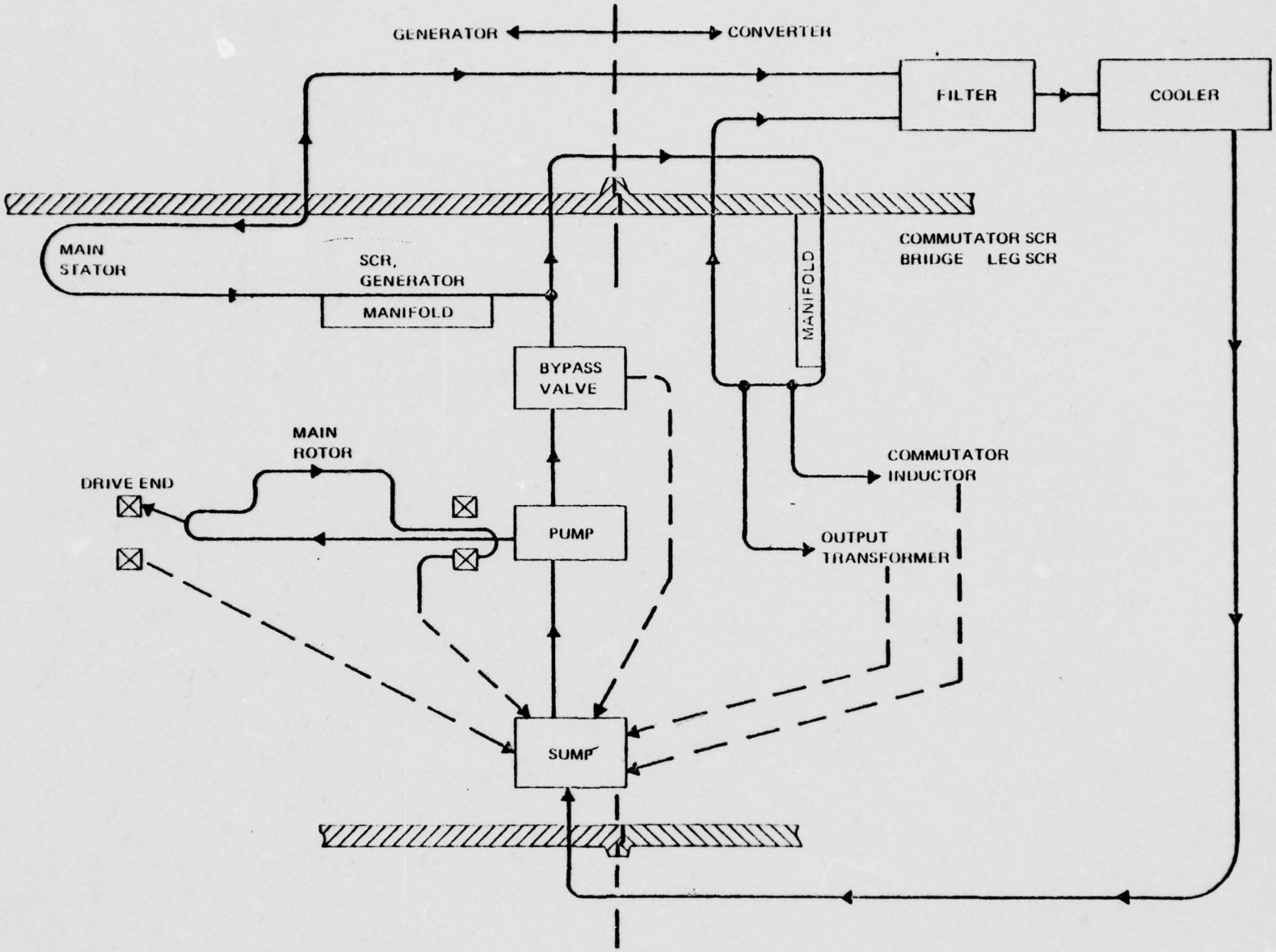


Figure 4-4. Bendix CFG Diagram Oil Flow

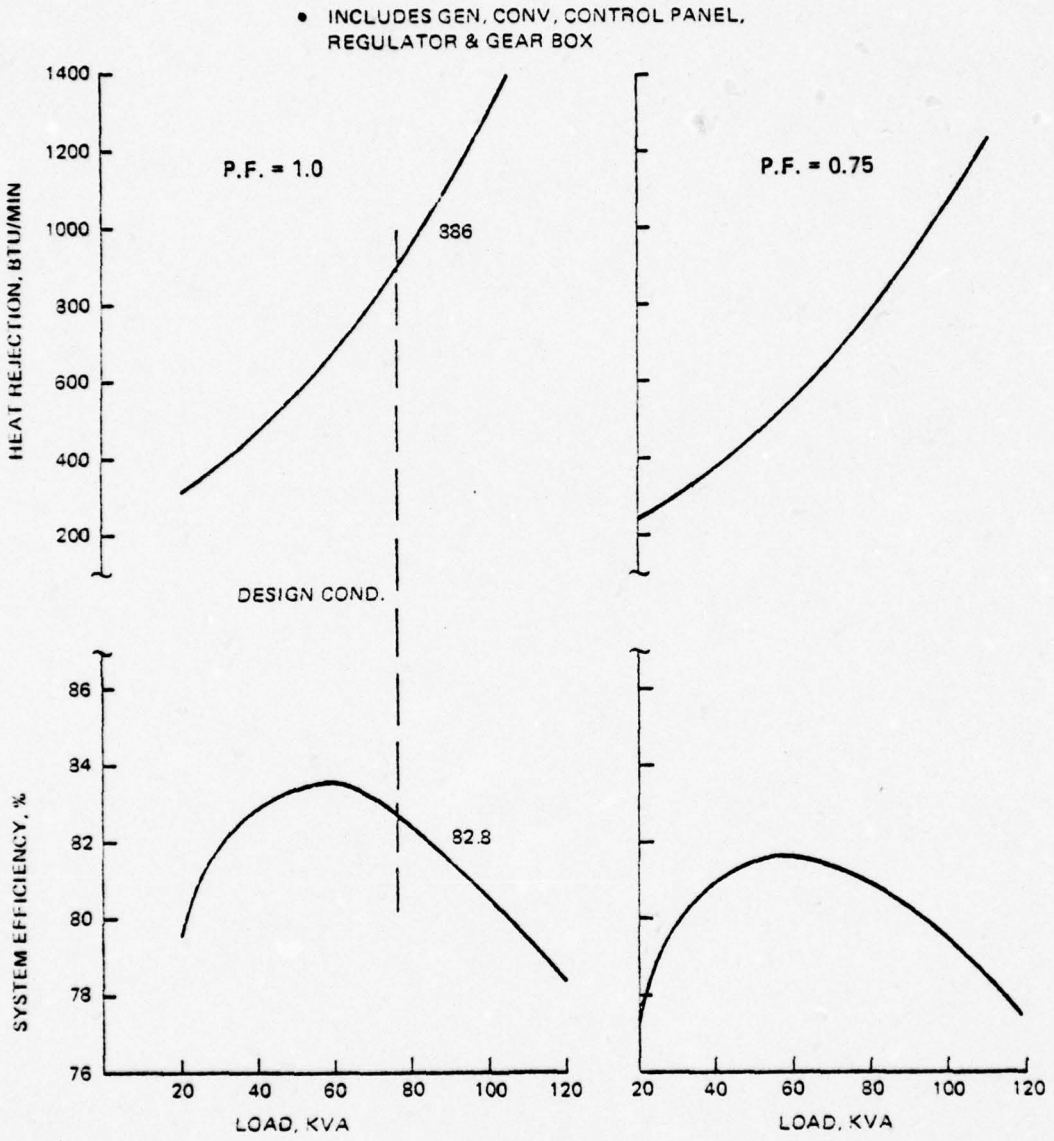


Figure 4-5. Bendix CFG System Efficiency and Heat Rejection Requirements

temperature.

The CFG could provide 28 vdc capability by connecting two extra windings on the delta bridges of the output transformer. This option would add approximately 3 lb to each CFG, but would add complexity to external power operation.

4.1.1.2 General Electric

The VSCF system proposed for the prototype (F-14A) consists of a 75KVA oil-cooled and lubricated generator, an in-line gear box, and a separately mounted converter/controller which is also oil cooled.

The generator is a wound rotor, brushless, synchronous machine containing a permanent magnet generator, rotating exciter, and rotating rectifiers. The design of the generator includes recent developments in the state-of-the-art of materials processing and construction technologies which permit design flexibility in order to satisfy specific application requirements while maintaining desired reliability goals.

Power for VSCF system control and the exciter field of the generator is supplied by the permanent magnet generator. The PMG is a part of the main rotor assembly and is mounted at the drive end of the generator. It is a short circuit and an air stabilized single phase machine.

Both stator and rotor of the permanent magnet generator are high efficiency electromagnetics and are easily cooled. Temperatures in these components are lower than in the main rotor or stator and afford additional margin for long life and high reliability.

The VSCF generator is capable of supplying approximately 65% more kva than the system rating to provide the reactive energy required by the naturally commutated converter. The generator frequency will be high enough to provide a large number of converter SCR firings per cycle to obtain a smooth 400 Hz output wave. An input-to-output frequency ratio across the converter of approximately 3:1, at the minimum generator speed (base speed) is used with the six-phase generator.

The gearbox will be an in-line speed increaser (3.24/1 step-up ratio) utilizing a star-gear arrangement. An internal drive gear will mesh with the three equally spaced idler gears which in turn mesh with the driven rotor gear. The internal gear is flexibly mounted on the input shaft so that the reactions of the three idler gears may be equalized, compensating for any small errors that might be present. Thus only the idler bearings will carry the gear reactions.

The gearing will be housed within a high strength aluminum alloy casing. The gearbox will also contain two oil pumps for distributing and scavenging oil, a disconnect and a seal.

The generator/gearbox will be designed to operate over the engine input pad speed range of 3700/7400 rpm.

The VSCF converter/control unit selected as a baseline for the F-14A study includes the cycloconverter (frequency changer) which changes the variable high frequency output from the generator to precise 400 Hz, 3-phase power.

The unit also contains the control and protection circuits. These circuits and the low-level control circuits for the converter use microcircuits and new circuit techniques to reduce size and weight while improving reliability, maintenance, and electrical performance. The GE VSCF system block diagram is shown in Fig. 4-6.

The generator delivers variable frequency power to three identical frequency changers within the converter package. The frequency changers convert the variable frequency power to a constant 400-Hz power. There is one frequency changer for each output phase. Each frequency changer is programmed with a 400 Hz-reference wave and high-frequency generator derived firing and blanking waves to produce at the converter output an image of the 400-Hz input reference wave. Negative feedback is used around the converter to improve the waveshape and to lower the converter output impedance. A digital discriminator in conjunction with a crystal-controlled oscillator is used to produce the 3-phase, 400-Hz reference waves. This combination produces three accurately spaced reference waves and reduces problems with phase

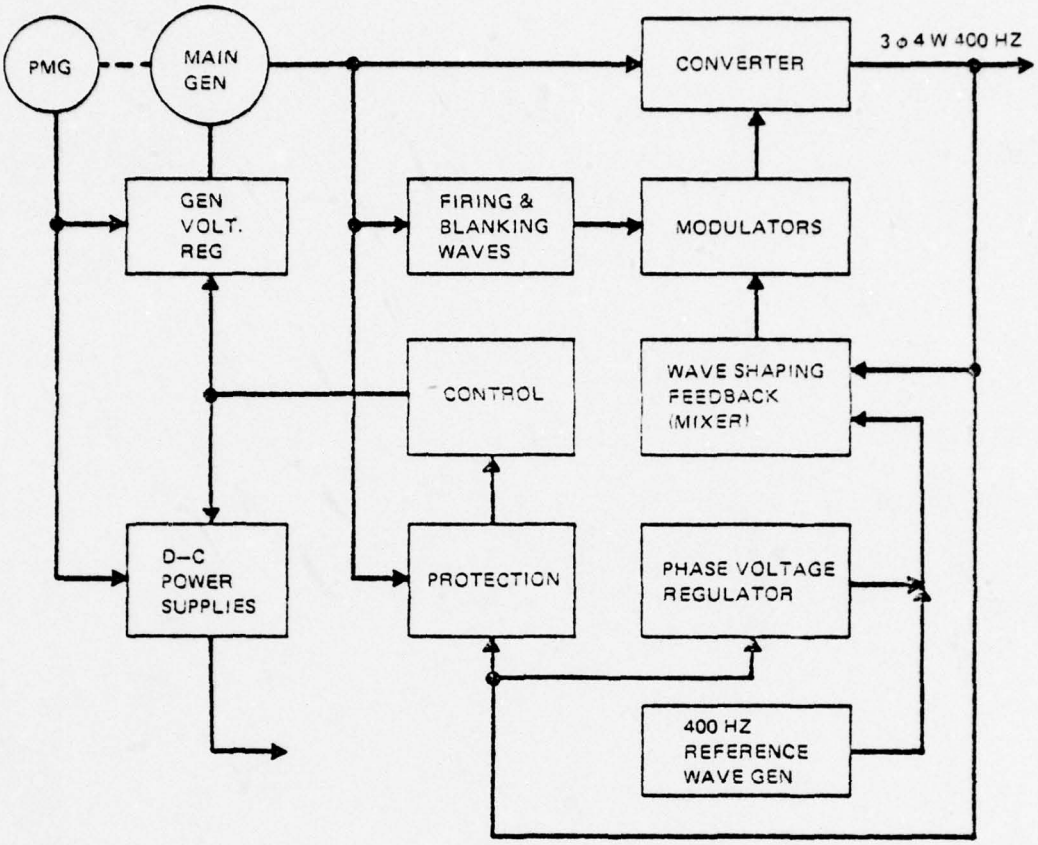


Figure 4-6. G. E. VSCF System Block Diagram

unbalance and drift.

Identical phase voltage regulators control the amplitude of each 400-Hz reference wave to produce balanced output voltages regulated to close limits.

The converter contains all the components which perform the conversion from the variable generator frequency to the constant 400-Hz, 3-phase output. The power switching is accomplished by silicon controlled rectifiers (SCR) mounted on heat sinks to remove the heat generated during switching and conduction. The firing of each SCR is controlled by a modulator in which three signals are mixed; a firing wave at generator frequency, a 400 Hz reference wave, and a d-c bias. The low-level conversion and all the protective circuitry is contained in the converter housing.

The cycloconverter is an inherently reliable frequency conversion device as it employs a natural commutation technique to control firing of the SCR's. Natural commutation means that the current is commutated (or switched) between SCR's only when the generator voltage passes through zero, thus, no energy storage devices are needed to commutate current. In a cycloconverter, should a missed commutation be experienced as a result of load disturbances, only an extremely short power loss results, as new opportunities to commutate will occur at their natural times. Recovery is quickly established and current transients resulting from the missed commutation are of short duration. Because there is no stored commutation energy, the SCR's are not overstressed in the recovery process and no failures are likely to occur. The control and protection functions to assure proper system operation are summarized in Table 4-2.

The generator oil inlet temperature will be limited to 300°F (149°C) under normal maximum continuous operation. The maximum allowable operating temperatures for critical cycloconverter components are listed below:

Item	Junction Temp	Case Temp
SCR	275°F (125°C)	237°F (114°C)
Output Filter Capacitor	----------	257°F (125°C)
Triple Modulator Hybrid	----------	230°F (110°C)
Misc Semiconductor	257°F (125°C)	237°F (114°C)

To ensure operation at these or lower temperatures, GE is limiting the cycloconverter inlet cooling oil to a maximum of 160°F (71°C). The VSCF heat rejection and system efficiency projections are shown in Fig. 4-7.

GE proposed an integral 100 amp, 28 volt transformer rectifier (TR) consisting of a transformer, bridge rectifier, and filter, as part of the cycloconverter. This TR option would weigh 8 lb and require 270 cu in. The baseline selected for comparison with the competing designs does not include this option.

4.1.1.3 Westinghouse

The proposed VSCF system consists of a 75-kva, oil-cooled, 6-phase, 1200 - to 2400-Hz brushless generator and an air-cooled converter. The generator includes the following major components:

- Main a-c generator (salient pole)
- A-C exciter (stationary field)
- Rotating rectifier (for excitation of the main generator)
- Permanent magnet generator (flux switch type)
- Current transformers for system control and protection
- Oil pump
- Quick assembly disconnect (QAD)
- Gearbox.

The converter includes the cycloconverter and its associated controls plus the genera-

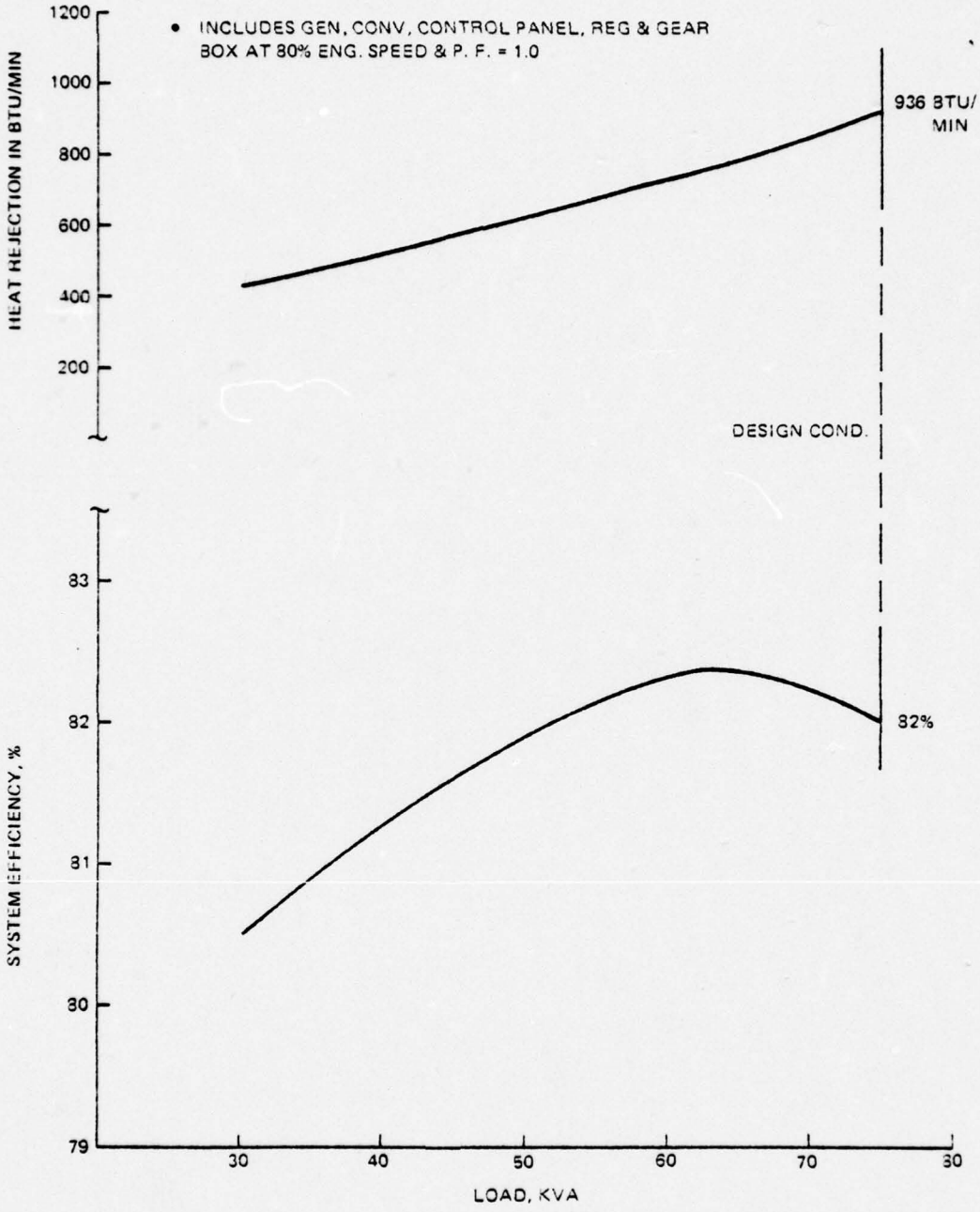


Figure 4-7. G. E. VSCF System Efficiency and Heat Rejection Requirements

tor voltage regulator and the system control and protective functions. The system block diagram is shown in Fig. 4-8.

The frequency changer is a direct, a-c to a-c converter using a high frequency generator and cycloconverter. The cycloconverter power circuit employs two three-pulse SCR groups in a double wye connection with interphase transformer, requiring a six-phase generator as shown in Fig. 4-9. This arrangement produces a six-pulse ripple. By combining two three-pulse converters in this way, the device utilization is the same as in the bridge circuit. An additional advantage, as compared to the bridge, is that the commutated currents are halved. On the other hand, the rms input current drawn from the generator is somewhat higher.

Because the SCR's conduct current in only one direction, two sets or "banks" of devices are used to carry the positive and negative load current respectively.

The SCR devices of each bank are fired at instants such that the desired output waveform is produced by combining segments of the generator phase voltages. The oncoming device is always connected to a phase more positive than the outgoing device; this is a necessary condition for natural commutation to take place.

The final output voltage waveform, synthisized from half cycle sections of the positive and negative bank waveform, is fed to the output filter ($L_F C_F$) which removes the six-pulse ripple, and thus a low distortion output is obtained at the load terminals. The input current wave of the naturally commutated cycloconverter, which always lags the corresponding generator voltage, is not a pure sinewave; it contains discrete steps corresponding to the conduction intervals of the converter SCR's. As a result, the rating of the generator has to be such that it can handle the necessary reactive and harmonic current.

The cycloconverter is controlled by comparing a sinewave reference voltage to reconstructed generator voltages. The method uses integration control to average the difference between generator voltage and reference voltage to determine the

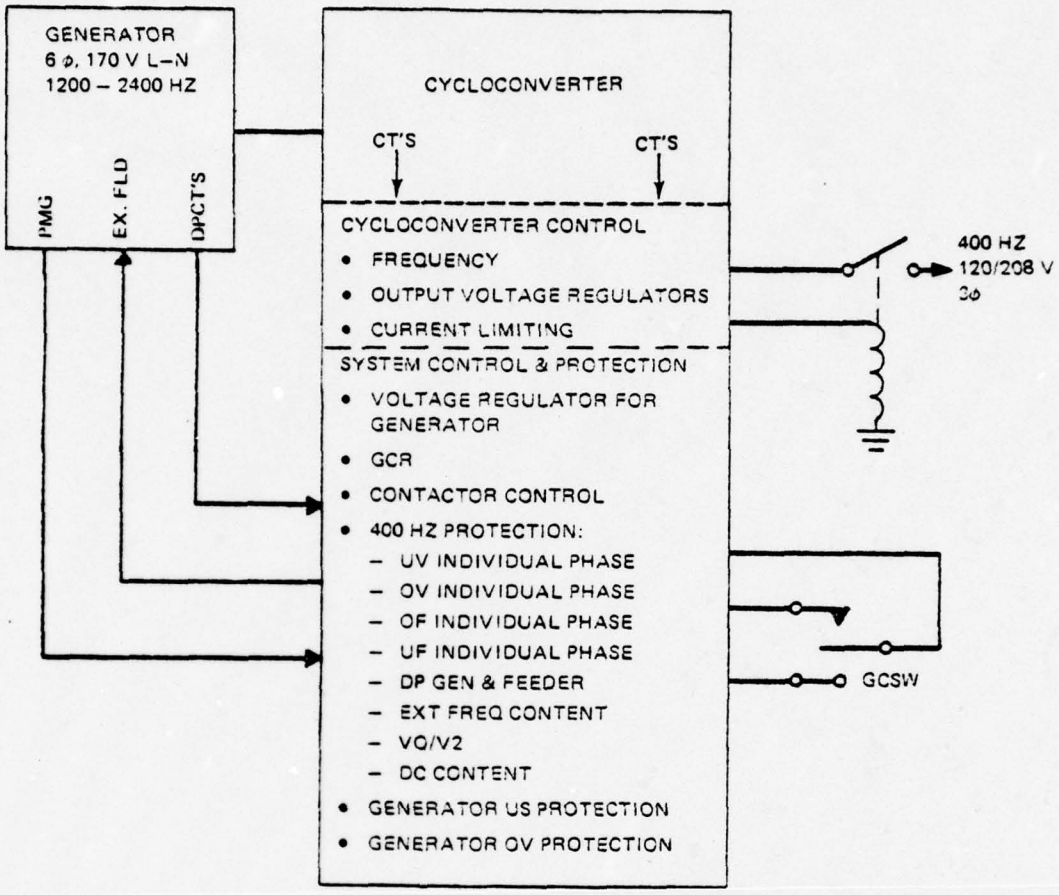


Figure 4-8. Westinghouse Cycloconverter VSCF Block Diagram

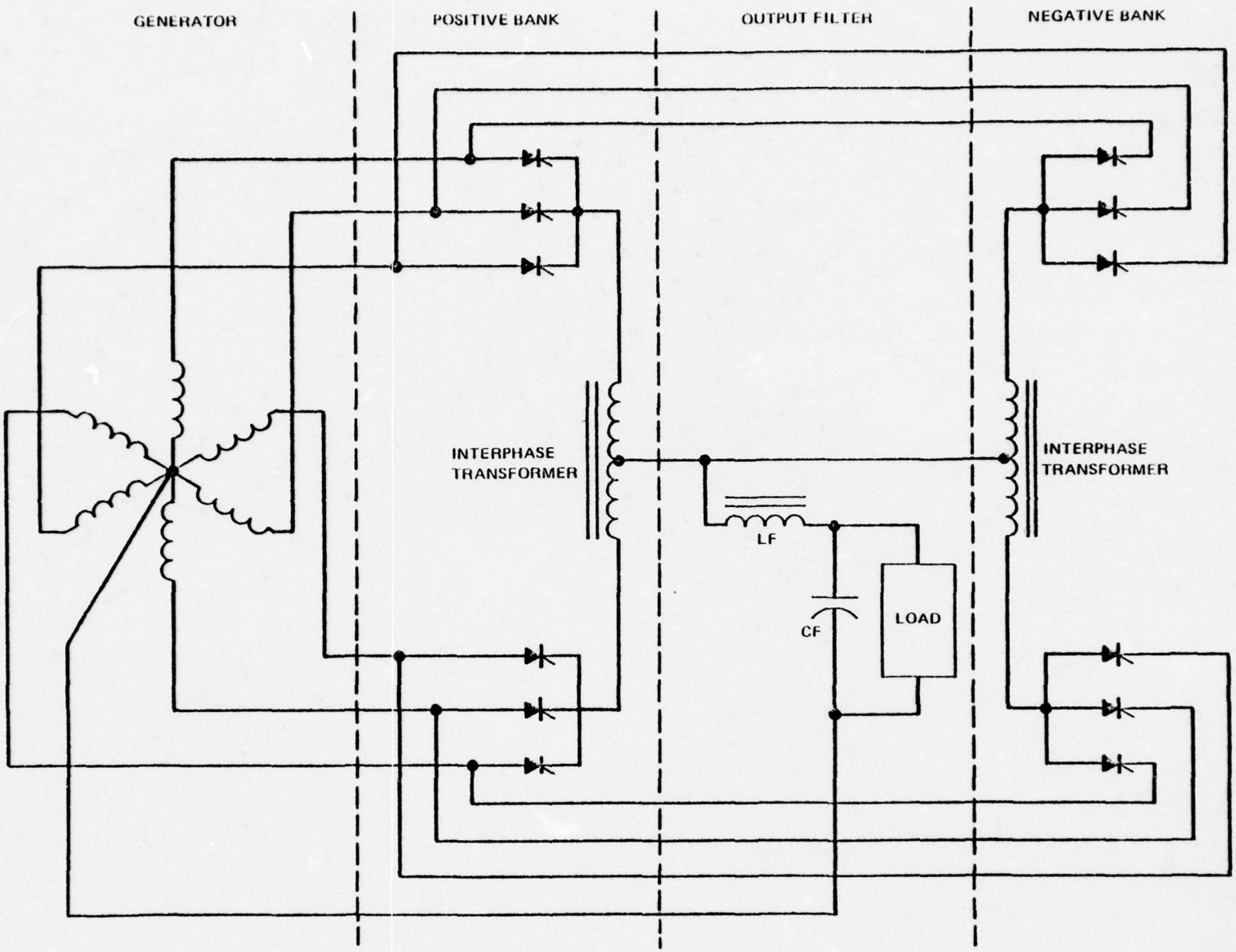


Figure 4-9. Westinghouse VSCF Basic Power Circuit

proper time to switch to the next SCR. The integral control method is superior to the conventional sinewave crossover method because it minimizes the effects of generator waveform distortion and sudden voltage transients. Limit controls are also used to assure that the oncoming SCR is not switched on too soon or too late. This prevents output voltage waveform distortion due to failures in SCR commutation.

System control and protective functions in accordance with MIL-E-23001A are included in the converter and are listed in Table 4-2.

The oil cooled generator is designed to operate with an oil flow of 4 to 5 gpm at maximum continuous oil inlet temperature of 300°F (149°C). The air cooled converter is designed to operate with 160°F (71°C) maximum air inlet temperature to keep the temperature of the SCR's below 212°F (100°C). The projected heat rejection and system efficiencies are shown in Fig. 4-10.

Westinghouse evaluated the capability to supply d-c power from the converter. One approach would be to obtain the power from the six-phase input to the cycloconverter. Due to cycloconverter operation the input waveforms are very distorted; therefore, it would be necessary to regulate the d-c output. The resulting TR would be more complex and weigh more than a conventional nonregulated TR unit. Westinghouse concluded that a separate TR appears to be the most practical approach.

4.1.2 AC/DC Power Distribution Section

4.1.2.1 F-14A Power Distribution

The F-14A electrical power distribution is shown in Fig. 4-11 and illustrates the split bus design made necessary by the use of the IDG's.

The electrical power distribution system enables application of power from any of the generating sources to appropriate buses. The distribution system includes wiring, and relays and contactors that control the power to eight three a-c and seven d-c buses and from the buses to the input side of each system circuit breaker. The output side of the circuit breaker(s) is considered a part of each system circuit, not part of power distribution. The weapon replaceable assemblies (WRA) and com-

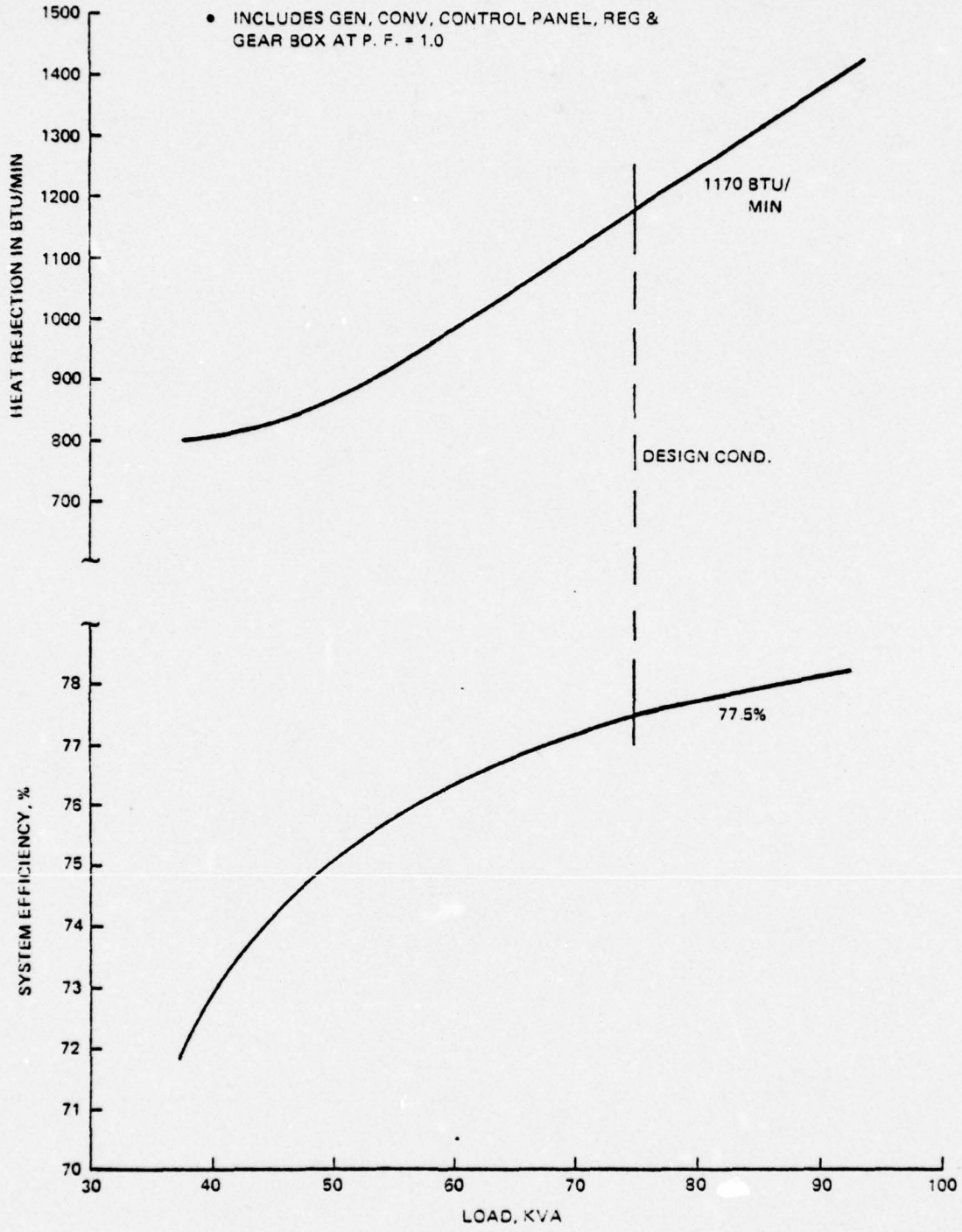


Figure 4-10. Westinghouse VSCF System Efficiency and Heat Rejection Requirements

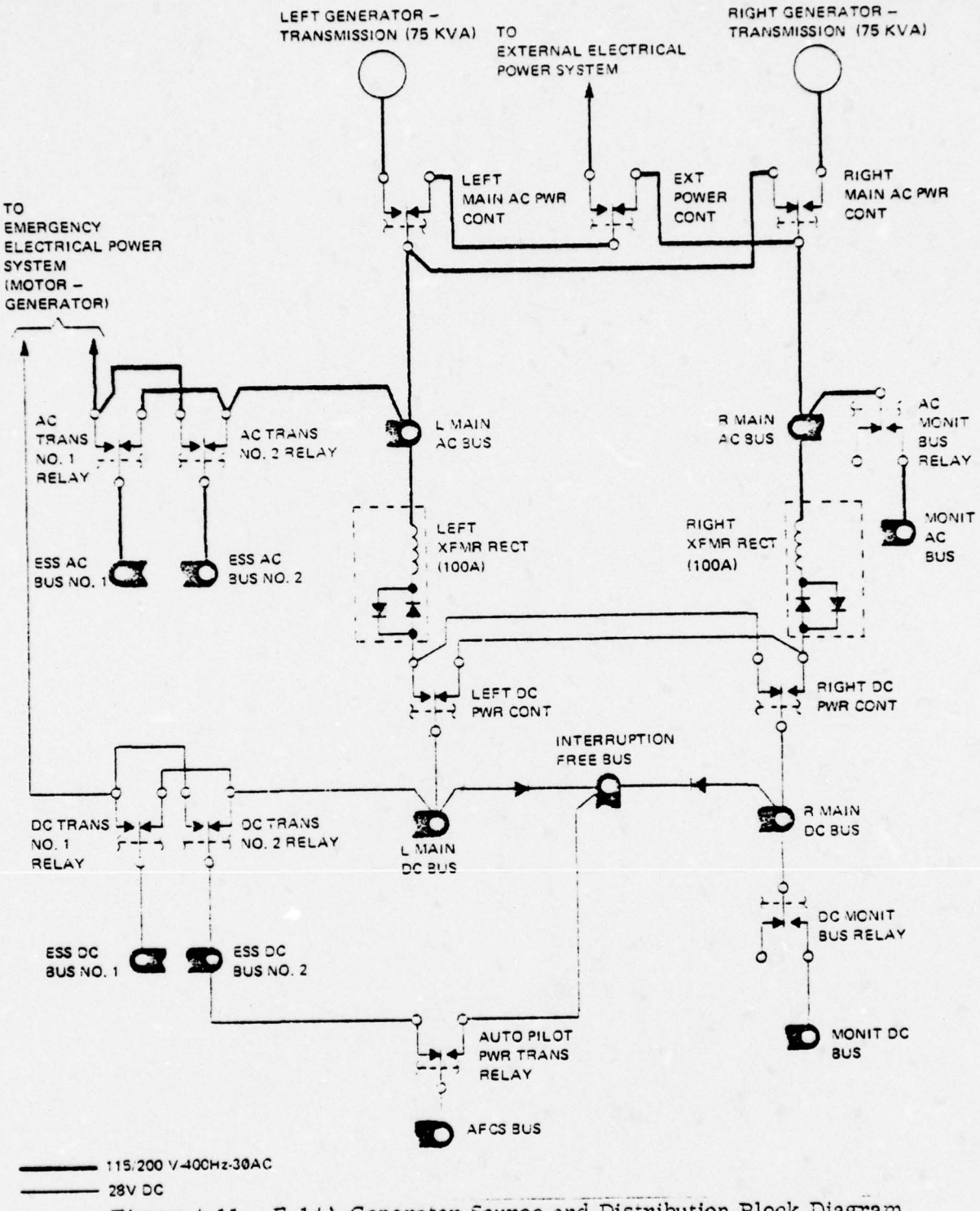


Figure 4-11. F-14A Generator Source and Distribution Block Diagram

ponents of the electrical power distribution system are listed in Table 4-3 and are described below. The WRA's and components of the a-c generator, external and emergency electrical power systems are listed in Table 4-4.

- A-C Power Contactor Assembly - The a-c power contactor assembly, at fuselage station 353 on the left side of the aircraft, contains the external a-c power contactor, and left and right main a-c power contactors
- A-C Power Switching Assembly - The a-c power switching assembly, at fuselage station 353 on the left side of the aircraft, contains the d-c monitor bus relay and the a-c essential power transfer no. 1 and 2 relays
- D-C Power Switching Box Assembly - The d-c power switching box assembly, at fuselage station 345 on the right side of the aircraft, contains the left and right d-c power contactors, the d-c monitor bus relay, and the d-c essential transfer No. 1 and 2 relays
- Left and Right Glove Switching Assemblies - The glove switching assemblies (one in each wing glove area) contain relays for control of electrical and electronic components and systems
- A-C Left Main Circuit Breaker Panel - The a-c left main (9 AC L MAIN) circuit breaker panel is aft of the naval flight officer (NFO) seat, on the Left side, at fuselage station 345. This panel contains circuit breakers that supply left main a-c bus power to nonessential electrical and electronic systems
- A-C Right Main Circuit Breaker Panel - The a-c right main (7 AC R MAIN) circuit breaker panel is aft on the NFO seat, on the left side, at fuselage station 345. This panel contains circuit breakers that supply right main a-c bus power to nonessential electrical and electronic systems
- A-C Essential No. 1 Circuit Breaker Panel - The a-c essential no. 1 (4 AC ESS 1) circuit breaker panel above the NFO right side console, at fuselage station 322, contains circuit breakers that supply essential a-c No. 1 bus

TABLE 4-3. ELECTRICAL POWER DISTRIBUTION ASSEMBLIES AND COMPONENTS

Ref. Des.	Nomenclature	Ref. Des.	Nomenclature
35A1	AC Right Main (7 AC R MAIN) Circuit Breaker Panel	36A2	DC Essential No. 2 (3 DC ESS 2) Circuit Breaker Panel
35A2	AC Essential No. 2 Phase A (5 AC ESS 2 ∅ A) Circuit Breaker Panel	36A3	Pilot DC Essential (2 DC ESS) Circuit Breaker Panel
35A3	AC Essential No. 1 (4 AC ESS 1) Circuit Breaker Panel	36A4	DC Main (10 DC MAIN) Circuit Breaker Panel
		66A6	AC Power Contactor Assembly
35A4	AC Essential No. 2 Phase B and C (3 AC ESS 2 ∅ B & C) Circuit Breaker Panel	67A2	AC Power Switching Assembly
		67A3	DC Power Switching Box Assembly
35A5	AC Left Main (9 AC L MAIN) Circuit Breaker Panel	77A1	Electrical Power System Test Panel
35A6	Pilot AC Essential (1 AC ESS) Circuit Breaker Panel	772A1	Right Glove Switching Assembly
35T1	Transformer (26 V AC)	773A1	Left Glove Switching Assembly
36A1	DC Essential No. 1 (6 DC ESS 1) Circuit Breaker Panel		

TABLE 4-4. A-C GENERATOR, EXTERNAL, AND EMERGENCY ELECTRICAL POWER ASSEMBLIES AND COMPONENTS

Ref. Des.	Section	Nomenclature
	AC Generator	
66A1		Voltage Regulator Control (Left)
66A2		Voltage Regulator Control (Right)
66A5		AC Power Sensor Assembly
66G1		Generator - Transmission (Left)
66G1		Generator - Transmission (Right)
T16A1		Master Generator Control Panel
	External Electrical Power	
66A3		Ground Power Monitor
66A4		External Power Panel
67R1		Transformer - Rectifier (Left)
67R2		Transformer - Rectifier (Right)
	Emergency Electrical Power	
67A1		Motor - General Control
67G1		Motor - Generator
67L1		Motor-Generator Solenoid Control Valve

power to electrical and electronic systems essential for safe flight

- A-C Essential No. 2 Phase A Circuit Breaker Panel - The a-c essential No. 2 phase A (5 AC ESS 2 Ø A) circuit breaker panel above the NFO left side console, at fuselage station 355, contains circuit breakers that supply essential No. 2 phase A bus power to electrical and electronic systems
- A-C Essential No. 2 Phase B and C Circuit Breaker Panel - The a-c essential No. 2 phase B and C (3 AC ESS 2Ø B&C) circuit breaker panel above the NFO left side console, at fuselage station 322, contains circuit breakers that supply essential a-c No. 2 phase B and C bus power and instrument a-c bus power to electrical and electronic systems
- Pilot A-C Essential Circuit Breaker Panel - The pilot a-c essential (1 AC ESS) circuit breaker panel on the lower portion of the left knee panel, contains circuit breakers that supply essential a-c No. 2 bus power to electrical and electronic systems
- D-C Main Circuit Breaker Panel - The d-c main (10 DC MAIN) circuit breaker panel is aft of the NFO seat, on the right side, at fuselage station 345. This panel contains circuit breakers that supply left and right main d-c bus power, interruption-free d-c bus power, and AWG-9 d-c power to electrical and electronic equipment. This panel also contains the autopilot power transfer relay, used to switch power sources to the AFCS bus
- D-C Essential No. 1 Circuit Breaker Panel - The d-c essential No. 1 (6 DC ESS 1) circuit breaker panel above the NFO right side console, at fuselage station 335, contains circuit breakers that supply essential d-c No. 1 bus power to electrical and electronic systems essential for safe flight
- D-C Essential No. 1 Circuit Breaker Panel - The d-c essential No. 2 (8 DC ESS 2) circuit breaker panel is aft of the NFO seat, on the right side, at fuselage station 345. This panel contains circuit breakers that supply essential d-c No. 2 bus power to electrical and electronic systems

- Pilot D-C Essential Circuit Breaker Panel - The pilot d-c essential (2 DC ESS) circuit breaker panel, on the lower portion of the right knee panel, contains circuit breakers that supply essential d-c No. 1 and 2 bus power to electrical and electronic systems

- Electrical Power System Test Panel - The electrical power systems test (PWR SYS TEST) panel, on the NFO right side console, has a receptacle for connecting ground support test equipment, and a switch for selecting electrical power sources. Test equipment is used to check that power provided to the buses of the electrical power distribution system is within tolerance

- Transformer (26 VAC) - The 26-volt a-c transformer is below the NFO left side console, forward of fuselage station 345. It drops essential a-c No. 2 bus voltage from 115 to 26 volts for distribution to the navigation and instrument a-c buses.

4.1.2.2 AAES Power Distribution

The present F-14A bus distribution configuration was utilized as the starting point for evaluating various bus concepts. Four basic bus configurations were developed:

- Main a-c and d-c buses with split or parallel operation plus essential a-c and d-c buses
- Main a-c and d-c buses with parallel operation only
- Main a-c and d-c buses with parallel operation plus essential a-c and d-c buses
- Main a-c and d-c buses with split or parallel operation.

In addition, the use of separate TR's as on the present aircraft versus integral TR capability within the VSCF/CFG system was factored into the four basic bus configurations. A summary of the bus and TR configuration matrix studied is presented in Table 4-5 and each configuration is illustrated in Fig. 4-12 through 4-19.

TABLE 4-5. CANDIDATE POWER GENERATION CONFIGURATIONS

Configuration	Main AC		Essential AC		Main DC		Essential DC		TR
	Split	//	Split	//	Split	//	Split	//	
IA	X	X		X	X			X	Integral
IB	X	X		X	X			X	Separate
IIA		X				X			Integral
IIB		X				X			Separate
IIIA		X		X		X		X	Integral
IIIB		X		X		X		X	Separate
IVA	X	X			X	X			Integral
IVB	X	X			X	X			Separate

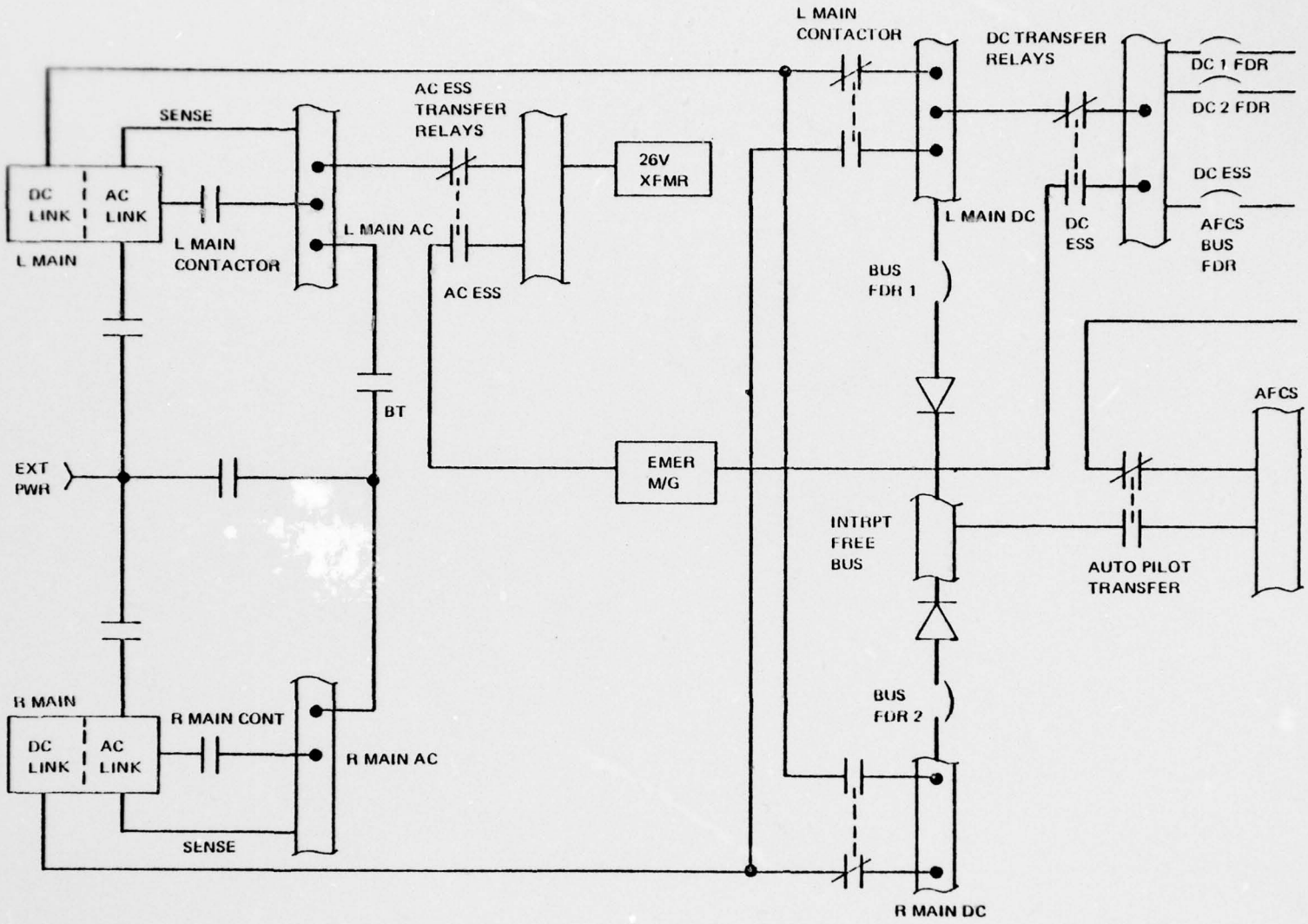


Figure 4-12. AAES Power Generation Configuration IA

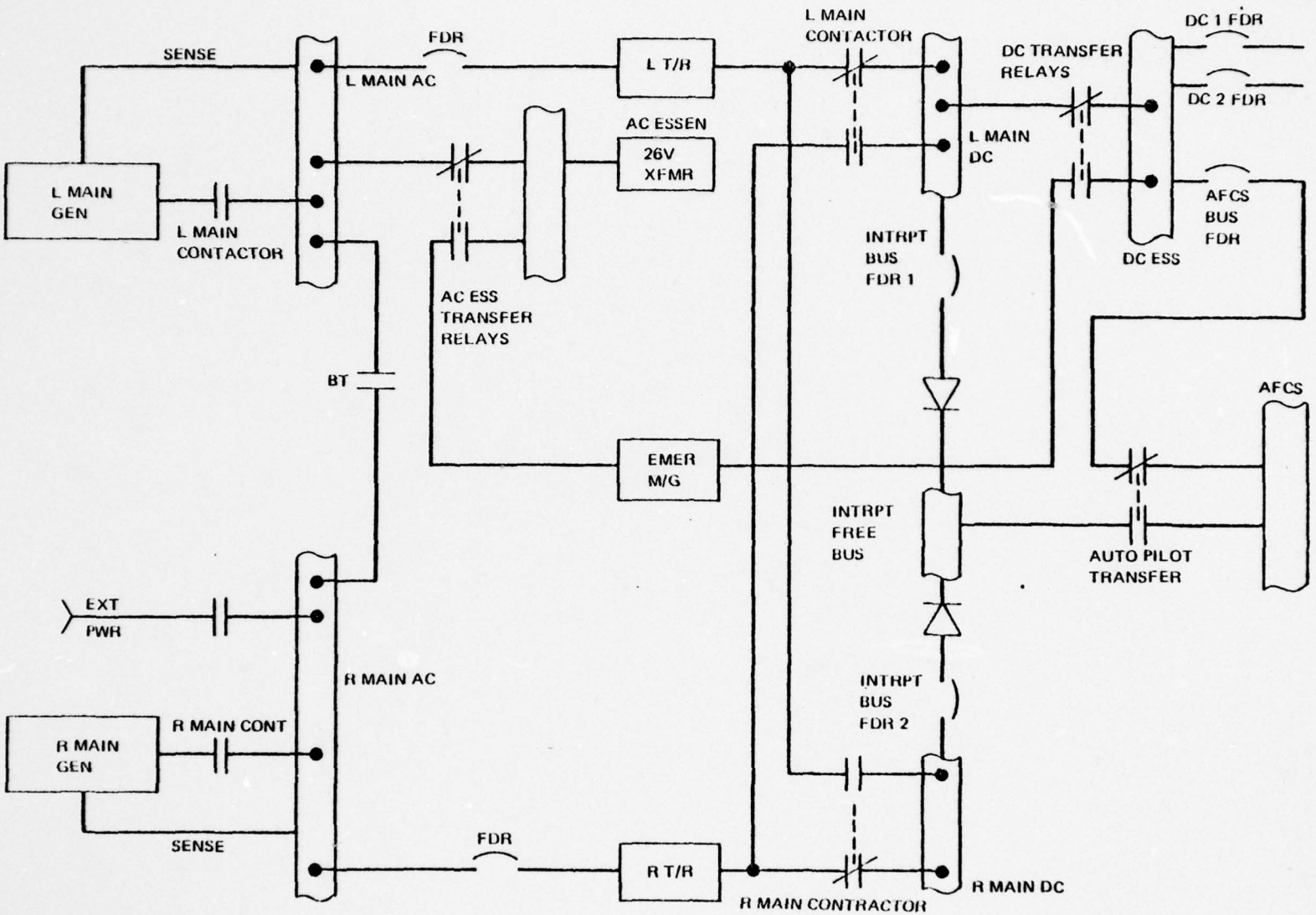


Figure 4-13. AAES Power Generation Configuration IB

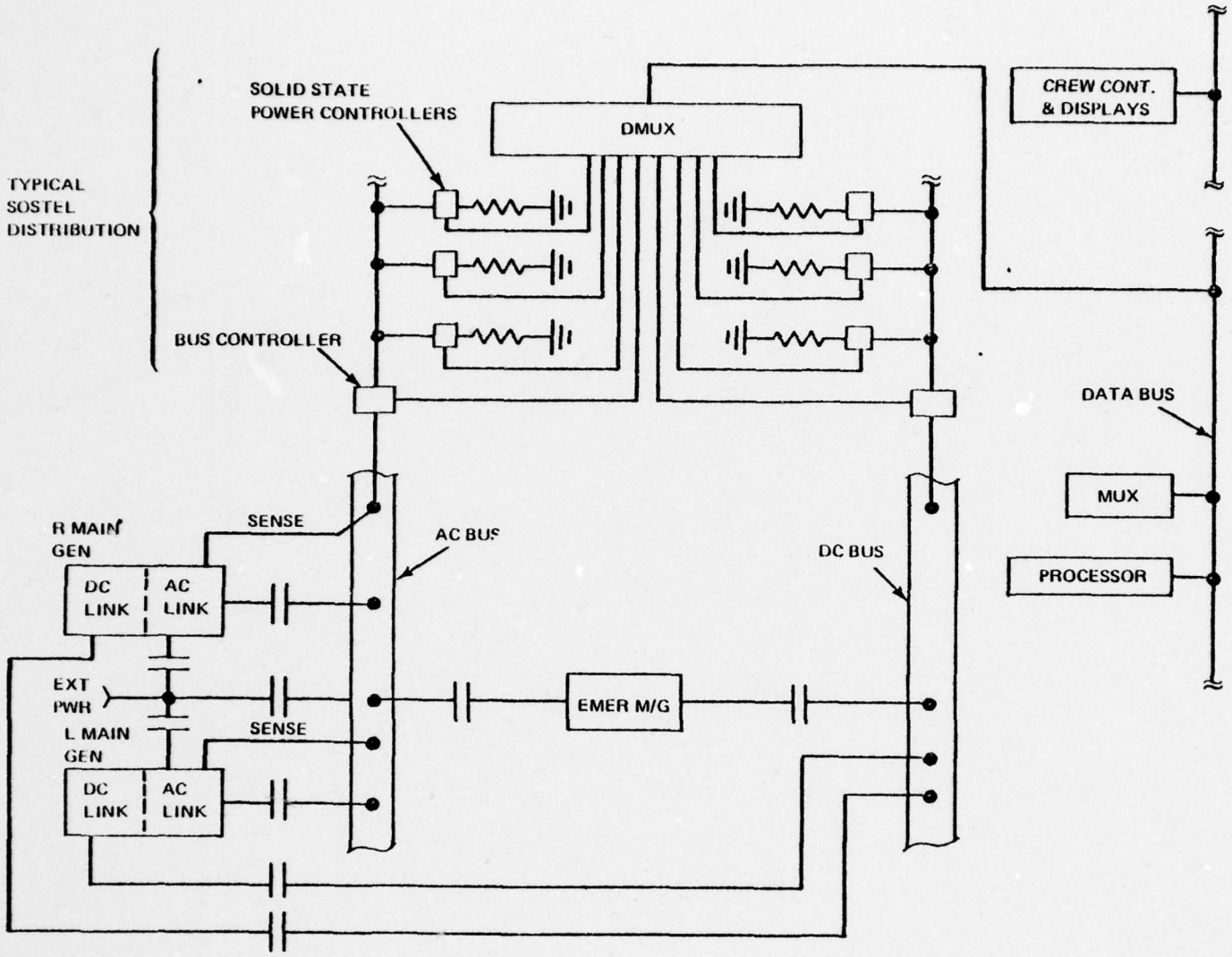


Figure 4-14. AAES Power Generation Configuration IIA

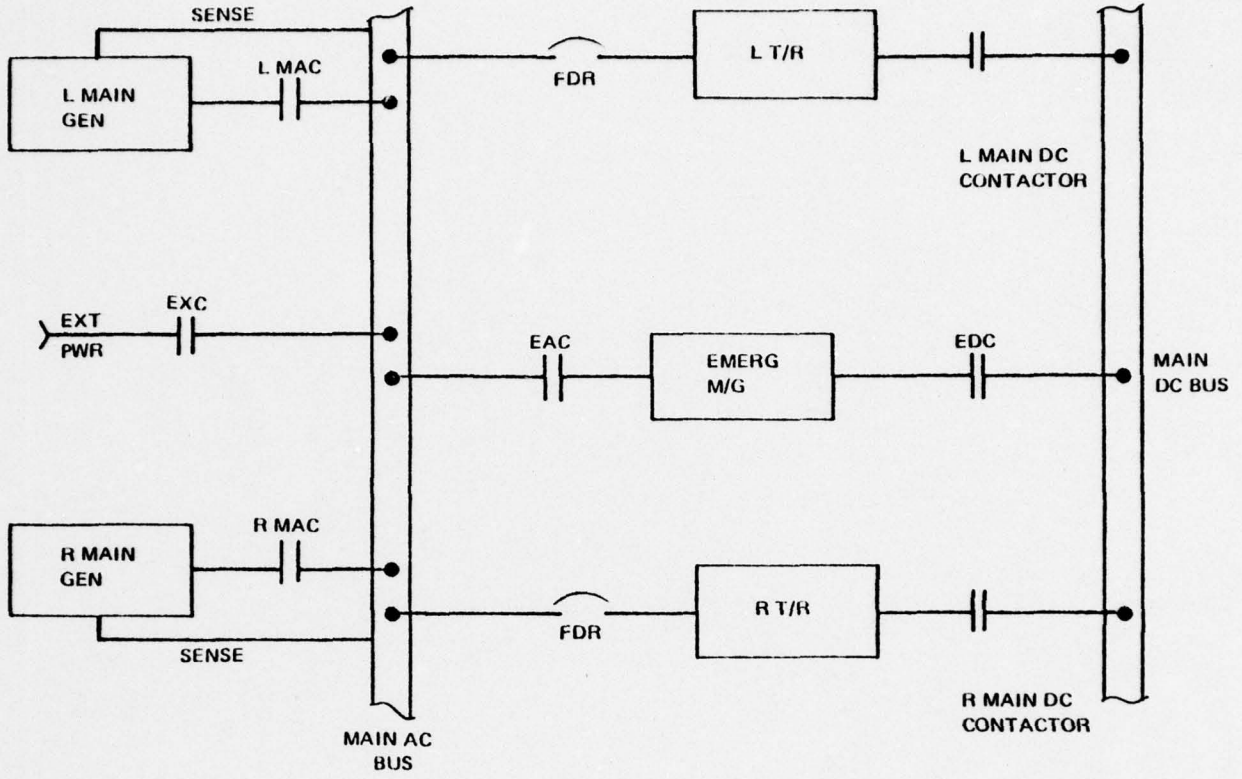


Figure 4-15. AAES Power Generation Configuration IIB

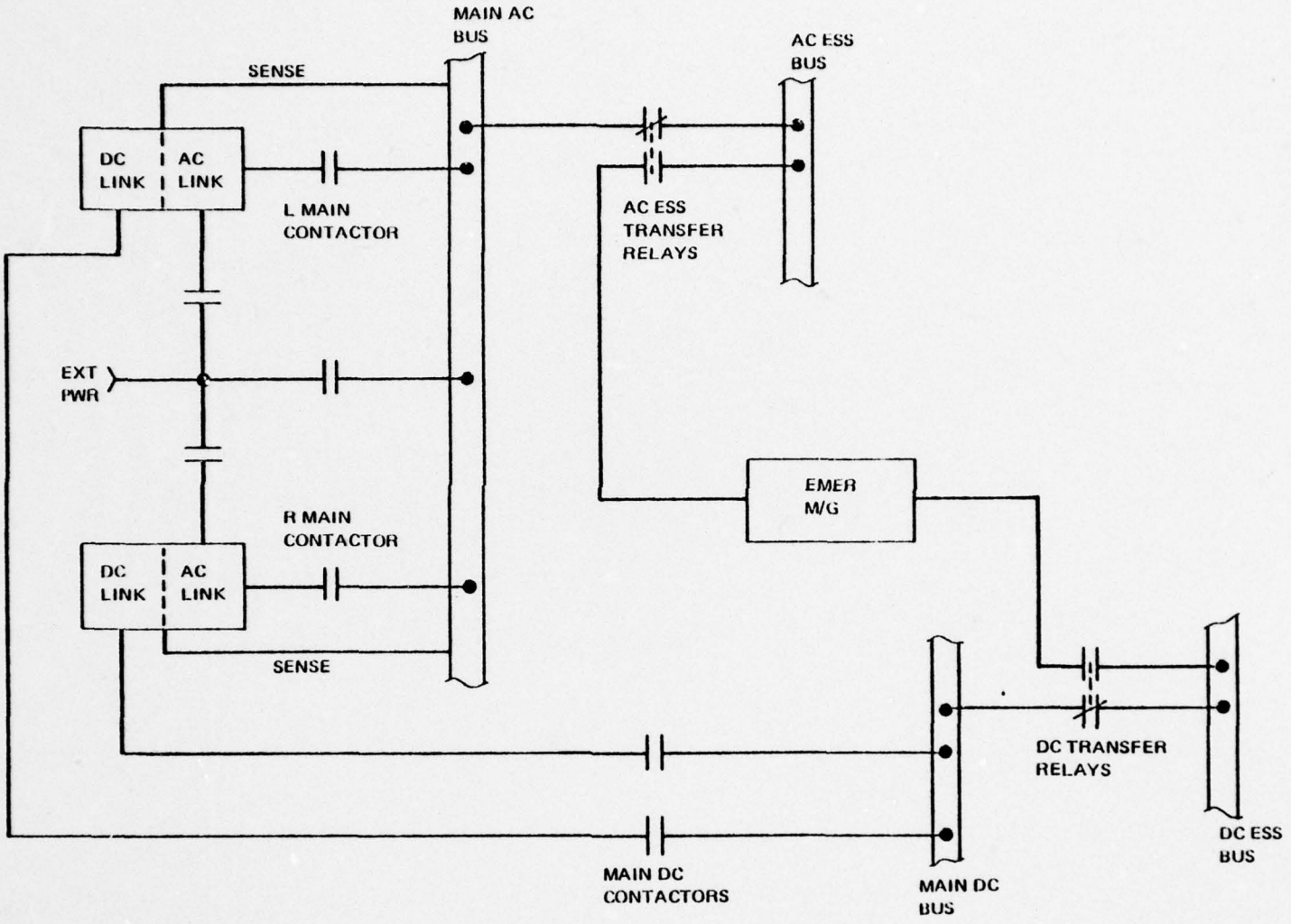


Figure 4-16. AAES Power Generation Configuration IIIA

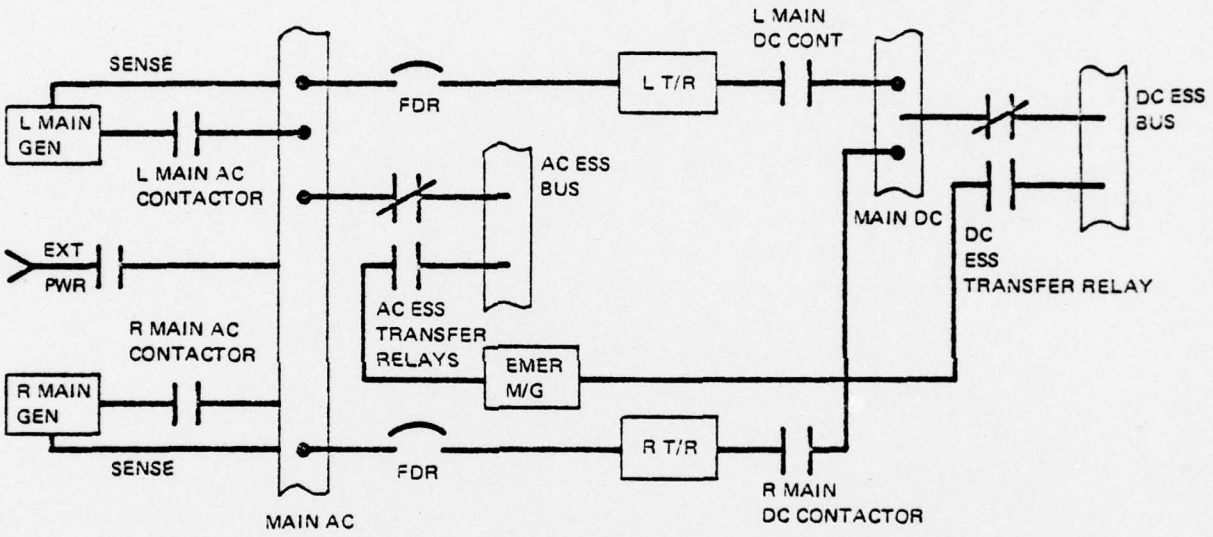


Figure 4-17. AAES Power Configuration IIIB

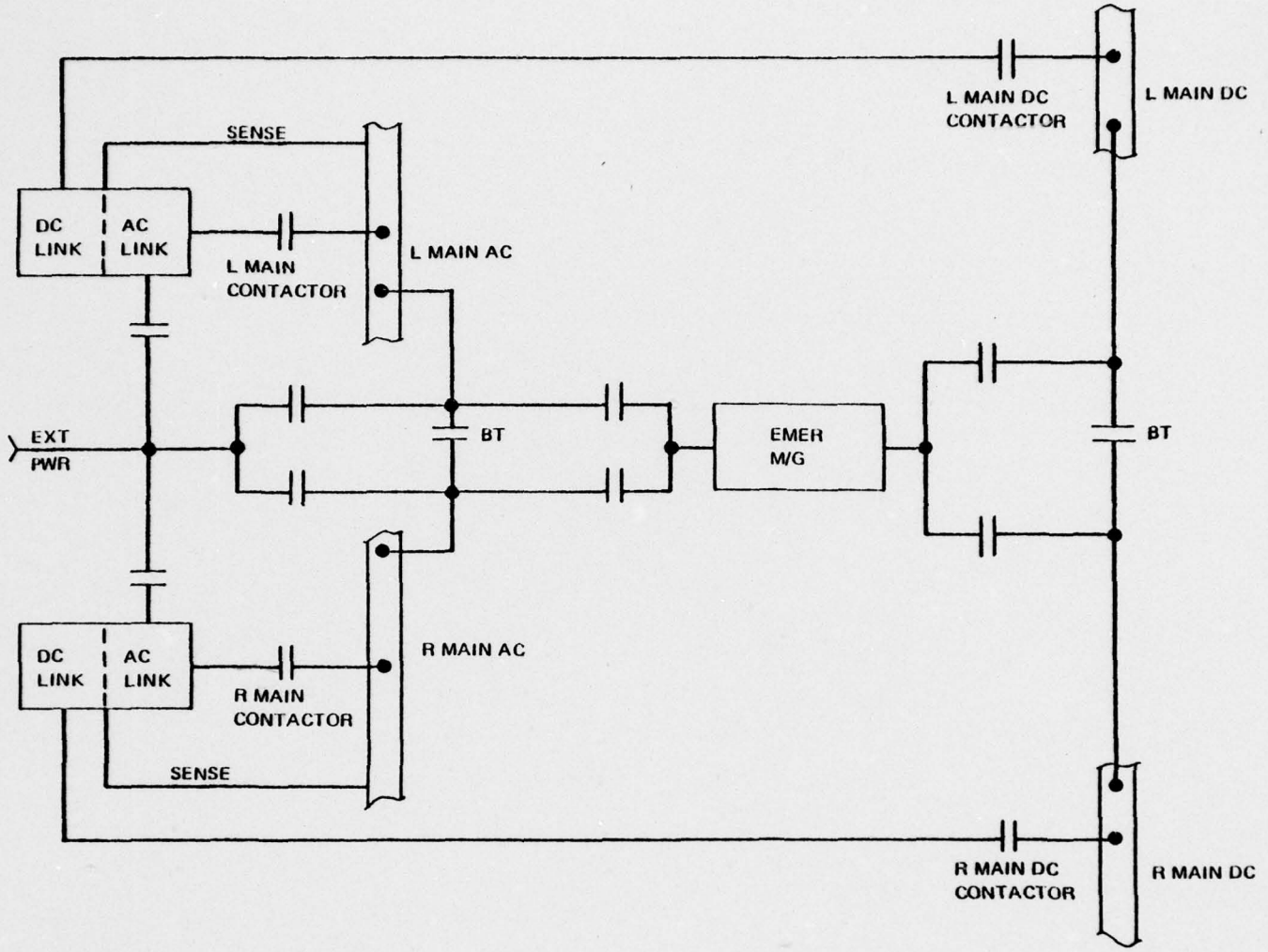


Figure 4-18. AAES Configuration IVA

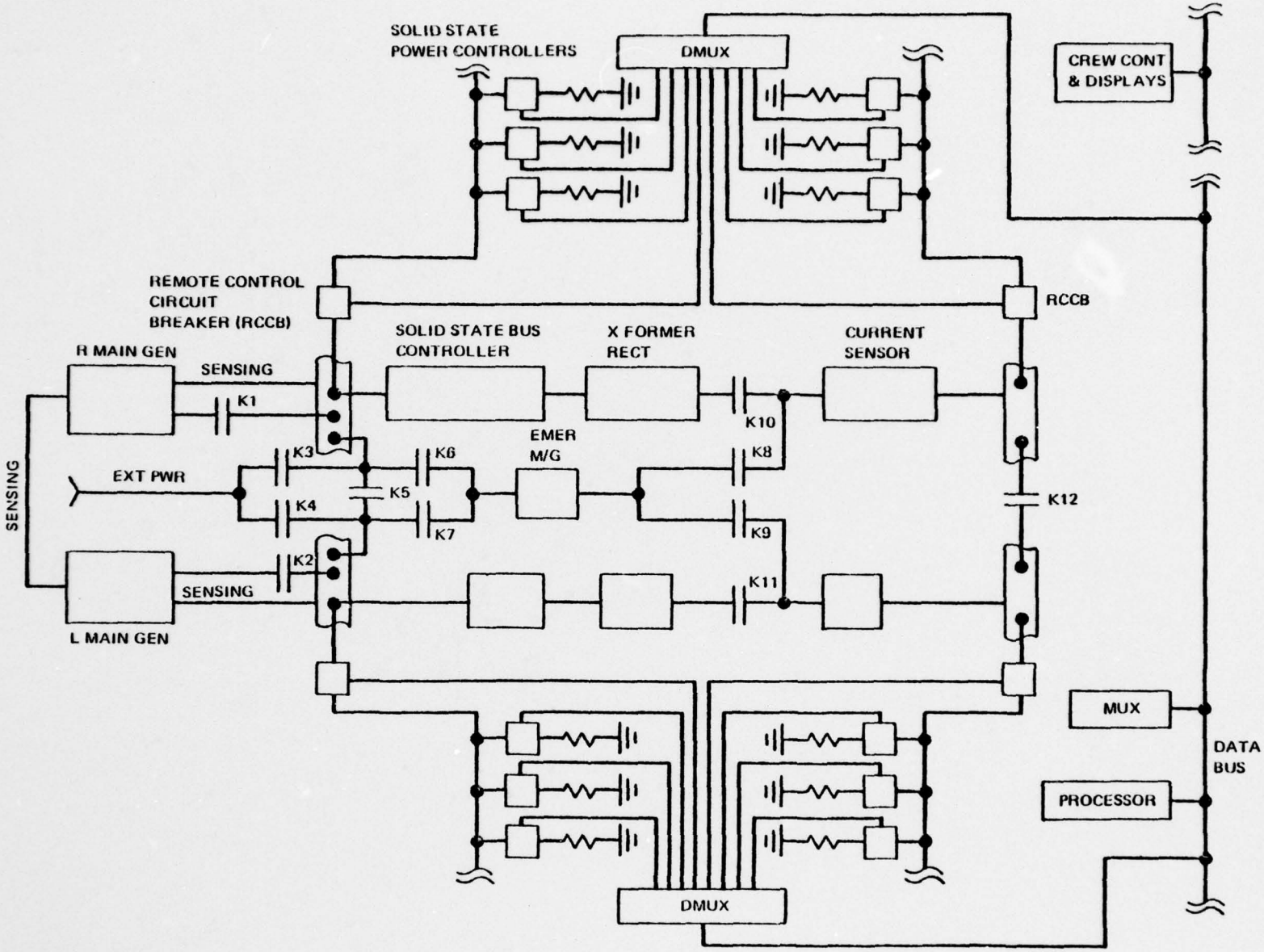


Figure 4-19. AAES Power Generation Configuration IVB

The candidate configurations were qualitatively assessed for operational complexity, system integration, maximizing SOSTEL capability, TR integration and vulnerability. The results of this assessment are presented in Table 4-6.

A reliability evaluation was also performed and is discussed in detail in Subsection 4.3.2.1. As a result of the aforementioned analyses, Configuration IIB was selected as the baseline for the AAES prototype design.

4.1.3 VSCF/CFG Vehicle Integration Studies

4.1.3.1 Thermal Analysis

Thermal data submitted by the suppliers (Fig. 4-5, 4-7 and 4-10) were analyzed for cooling requirements with the design condition specified as a 75-kva-rated load at 80% engine speed (intermittant power) and a system load power factor of unity. This condition represents the maximum VSCF system heat dissipation during continuous operation at the critical design point for the IDG oil cooler. The nominal speed at this condition is 80% maximum rpm. A significant criterion in the analysis was the capability of the proposed system to have its rejected heat removed by the existing IDG oil cooler, eliminating the need for making modifications to the aircraft. With the exception of the Westinghouse cycloconverter, which requires air cooling, the proposed systems can be oil cooled using MIL-L-23699 oil. A tabularized comparison of the three systems is presented in Table 4-7.

Westinghouse proposed a VSCF system comprised of a variable frequency generator and a solid state cycloconverter. Cooling requirements specify an oil flow of 4-5 gpm to the generator system at a maximum inlet temperature of 300°F. The given efficiency curve for the cycloconverter is based on blast air cooling of that system. The converter would require approximately 6.5 lb/min at 62°F inlet temperature and 18 lb/min at 160°F air temperature. These air flows and temperatures are based on maintaining the silicon controlled rectifiers (SCR) in the cycloconverter below 100°C (212°F). However, the ECS in the F-14A is nearly at full capacity and the requirements of the Westinghouse cycloconverter exceed the available air cooling

TABLE 4-6. BUS CONFIGURATION ASSESSMENT

Config No.	Performance Effects	Operational Complexity	SOSTEL Usage	Vulnerability	TB Integration	Production Design & Install.	Total
IA	2	2	2	4	2	2	14
IB	2	2	2	4	3	2	15
IIA	4	4	4	3	2	4	21
IIB	4	4	4	3	3	4	22
IIIA	3	3	3	3	2	3	17
IIIB	3	3	3	3	3	3	18
IVA	4	3	4	4	2	3	20
IVB	4	3	4	4	3	3	21

Rating Factors:

1 Poor

2 Fair

3 Good

4 Excellent

TABLE 4-7. VSCF/CFG COOLING REQUIREMENTS

System	Heat Rejection, Btu/Min	Max Allowable Oil Temp, °F	Oil Flow, rpm	Oil Supply Temp, °F
Bendix CFG	886	185	3	160
			4	177
			5	180
			6	189
G. E. VSCF (Gen + Cycloconverter)	936	160	3.5	184
			6	208
Westinghouse VSCF (Gen Only)	930	300	4	185
			5	190

NOTES:
- 75 kva Gen Load
- 1.0 Power Factor
- 80% Max rpm

capability. In addition, the cycloconverter would have to be located in a force-cooled compartment where the needed volume (2340 cu in.) for storage of the appratus might necessitate equipment relocations and increased costs.

The Bendix system consists of a generator and a d-c link-type converter. These are integrated into a single, compact unit which is entirely oil-cooled with MIL-L-23699 oil. The maximum allowable oil inlet temperature to the system is 185°F and the oil flow should be 3-5 gpm for satisfactory heat dissipation under the most severe operational conditions. As indicated in Table 4-7 and Fig. 4-20, the capacity of the existing F-14A IDG oil cooling system is greater than required by Bendix's system and, therefore, the 185°F inlet temperature will not be exceeded for this system. Fig. 4-20 illustrates the oil supply temperature as a function of heat removed by the IDG cooler and flow rate for the Bendix CFG system. The design point is shown in this figure.

The VSCF system proposed by General Electric is similar to that of Westinghouse, and is comprised of a variable frequency generator and a solid state cycloconverter. However, unlike the proposed Westinghouse design, this system may be integrated and oil cooled with MIL-L-23699 oil. The given oil flow is 6 gpm through the system with the critical components again being the SCR's in the cycloconverter. Due to these components, the maximum allowable oil inlet temperature specified by GE to the cycloconverter is 71°C (160°F). As can be seen from Table 4-7 and Fig. 4-21, at the oil flow rate of 6 gpm, the IDG oil cooler capacity is not sufficient to meet the integrated system cooling requirements. To handle the VSCF heat load using the IDG oil cooler, the oil inlet temperature to the system must be 205°F (96°C), which is higher than the allowable maximum. General Electric decreased the required system oil flow rate from 6 gpm to 3.5 gpm in an effort to increase the capacity of the IDG oil cooler. However, the system cooling requirements still cannot be satisfied unless the oil inlet temperature to the system is 182°F (83°C), which is also higher than tolerable. Fig. 4-21 illustrates the oil supply temperature as a function of heat removed by the IDG cooler and flow rate for the GE VSCF system.

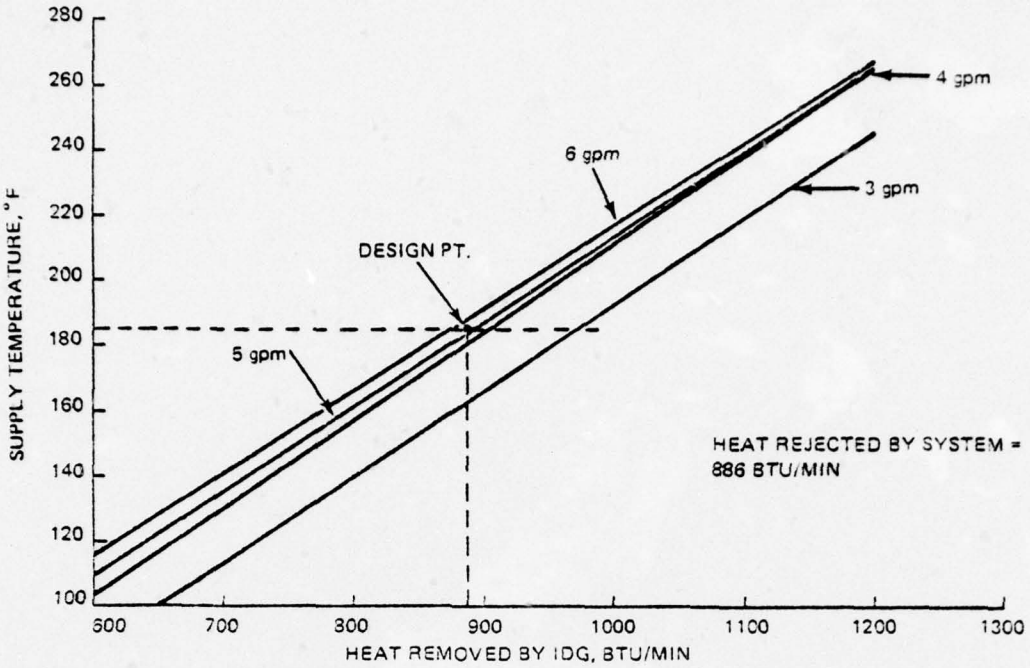


Figure 4-20. Oil Supply Temperature as Function of Heat Removed by IDG Oil Cooler and Flow Rate for Bendix CFG System

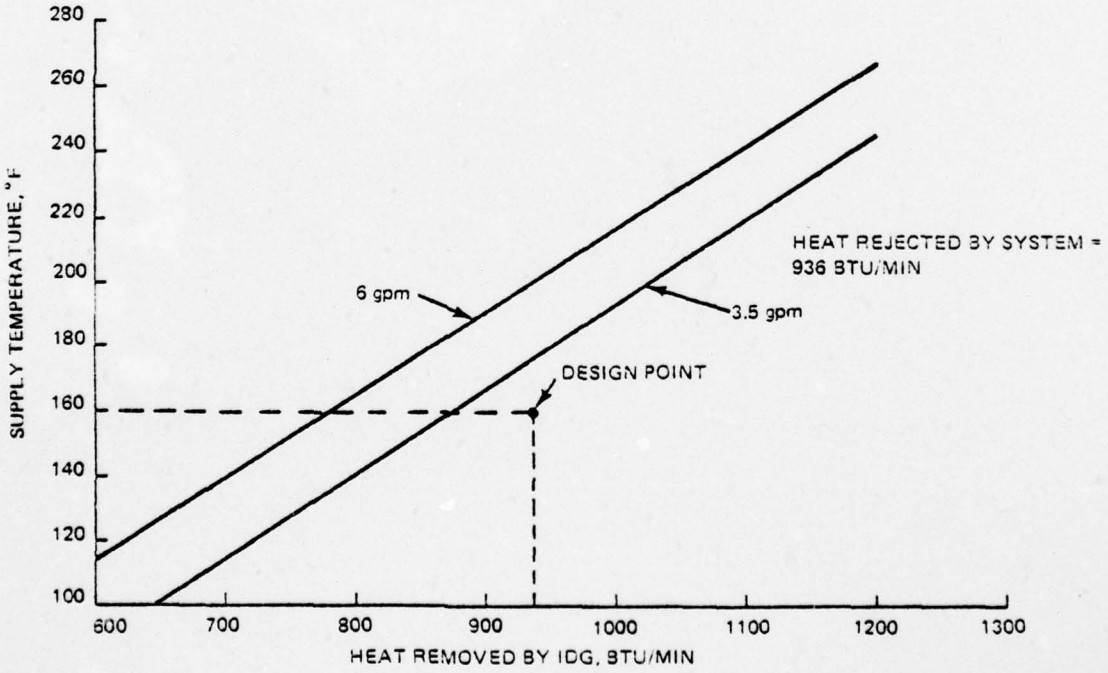


Figure 4-21. Oil Supply Temperature as Function of Heat Removed by IDG Oil Cooler and Flow Rate for General Electric VSCF System

The GE design point is shown in this figure.

The heat exchanger performance of the existing IDG oil cooler is the critical constraint in the thermal analysis of the VSCF system, establishing the capability of the heat exchanger to remove the heat being dissipated by that system. Review of the proposals indicates that the Bendix system is the only VSCF system whose cooling requirements can be satisfied by the existing IDG oil cooler. The VSCF system proposed by General Electric can be entirely oil cooled, but the maximum temperature of the inlet oil to the converter is only 160°F and the IDG oil cooler cannot remove the heat dissipated by the system and deliver the oil at this temperature. It should be noted that GE has made attempts to live with a lower oil flow rate through the system (3.5 gpm) than the 6 gpm indicated in the proposal, but the increased heat exchanger effectiveness of the IDG cooler is not sufficient to satisfy the cooling requirements of the system. The Westinghouse system specified a parallel cooling circuit for the VSCF system with the generator being oil cooled and the cycloconverter air cooled. Referring to Table 4-7, the indicated heat removal (1442 BTU/min) by the oil cooler would not be possible if the system were integrated and completely oil cooled. As in the case of the GE system, the maximum allowable temperature of the inlet oil to the converter would severely limit the capability of the IDG oil cooler to remove the dissipated heat from the VSCF system.

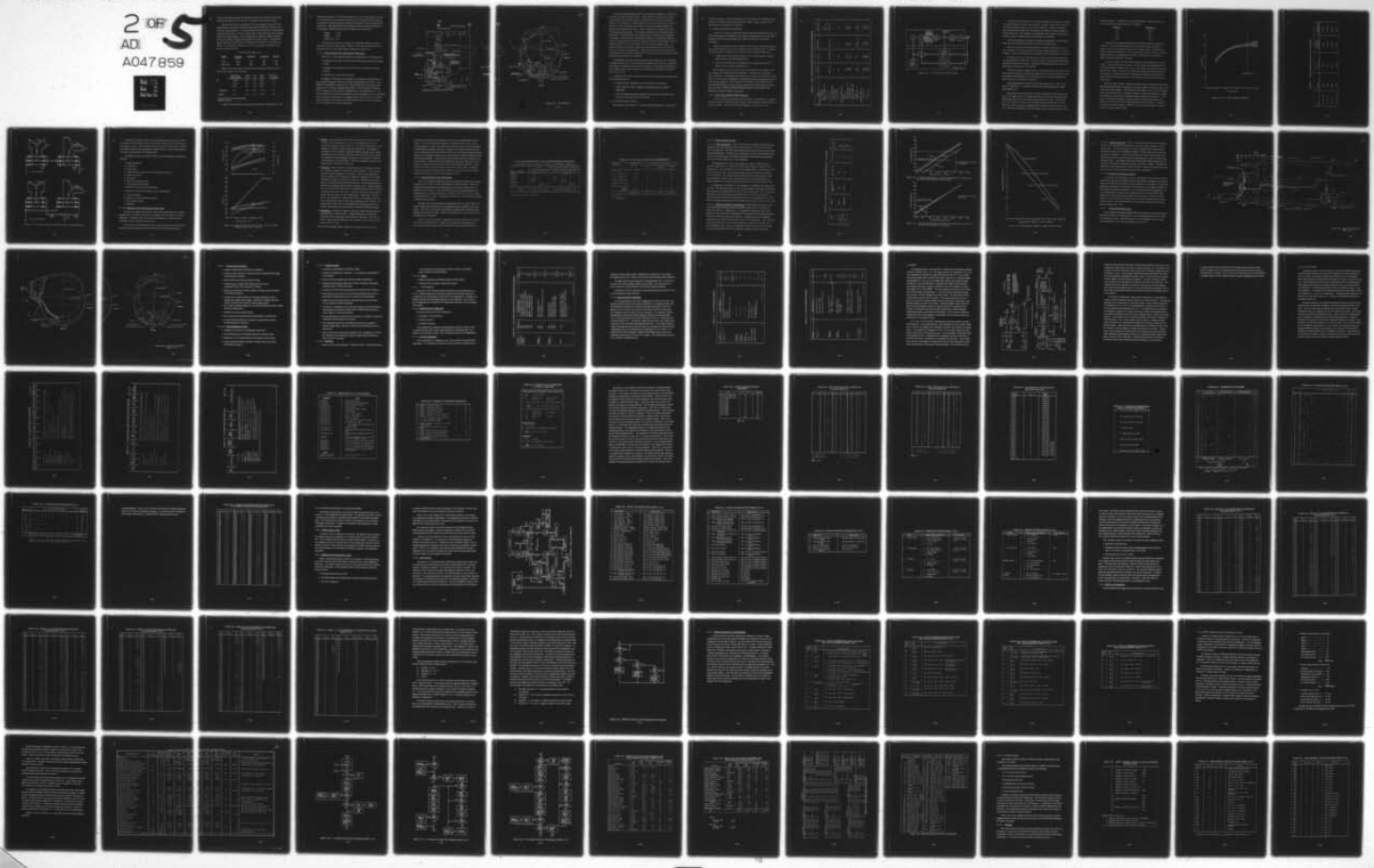
Further consideration of the Westinghouse or GE systems requires the implementation of an additional heat exchanger in series with the existing IDG cooler. The preliminary designs of an oil-fuel heat exchanger and an oil-air heat exchanger have been made. A four-pass, plate-fin, oil-to-fuel heat exchanger appears to be the best design because of the small pressure drop, low weight, and small volume. It should be noted that the GE design may be made compatible with the present IDG cooling loop via a nominal increase in the allowable oil inlet temperature and/or a more efficient integral gear design.

4.1.3.2 Engine Pad Interface Considerations

The present F-14A IDG is qualified for input speeds of 3700-7400 rpm. The

AD-A047 859 GRUMMAN AEROSPACE CORP BETHPAGE N Y F/G 9/3
ADVANCED AIRCRAFT ELECTRICAL SYSTEM (AAES). DEFINITION AND PROT--ETC(U)
JUL 76 G COTTER, H SIEGEL, P PISANI N62269-75-C-0392
UNCLASSIFIED NADC-76194-30-VOL-1 NL

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various vendor studies indicate the generator weig
minimum input speed can be increased, assuming

The table below shows a comparison of the a
engine IDG pad, and also the speeds currently bein
F401 (Rev) remote gearbox. It is not likely that th
cantly from those listed. Since the revised F401 i
there may be some changes. A lower design limit
based on the extreme cold day idle conditions for w
should be given to the probability of drawing full el
ditions. For either case, the upper limit of 7400
short overspeed conditions.

F-14 IDG Pad Speeds,

Engine	Min Idle (-60°F)	Nom Idle
TF30	4319	4880
F401 (Rev)	4251	4595

Several of the trade studies submitted includ
75 kva, Input Speed = 3700/7400 rpm):

	Speed Ratio (Input/Output)	Length, in.	Dia, in.
GE	1:3.24	5.0	9.5
	1:2.0	5.0	9.5
	1:1.4	5.0	9.5
Sundstrand	1:2	4.0	10.0
Bendix	1:2	2.0	----

*Separate gearbox of existing design
**Integral gear box

An inhouse study was made to estimate the w

this power requirement. An aluminum housing of 9.4 in. OD was assumed in order to be consistent with the generator diameter, and it was assumed that the internal oil scavenge and pressure pumps required for the generator would be sufficient for the gearbox. This study indicated the following allowances should be adequate for a well designed, lightweight gearbox that is integral with the generator:

Length:	3.0 in.
Weight:	8.0 lb
Power Loss:	2.0%

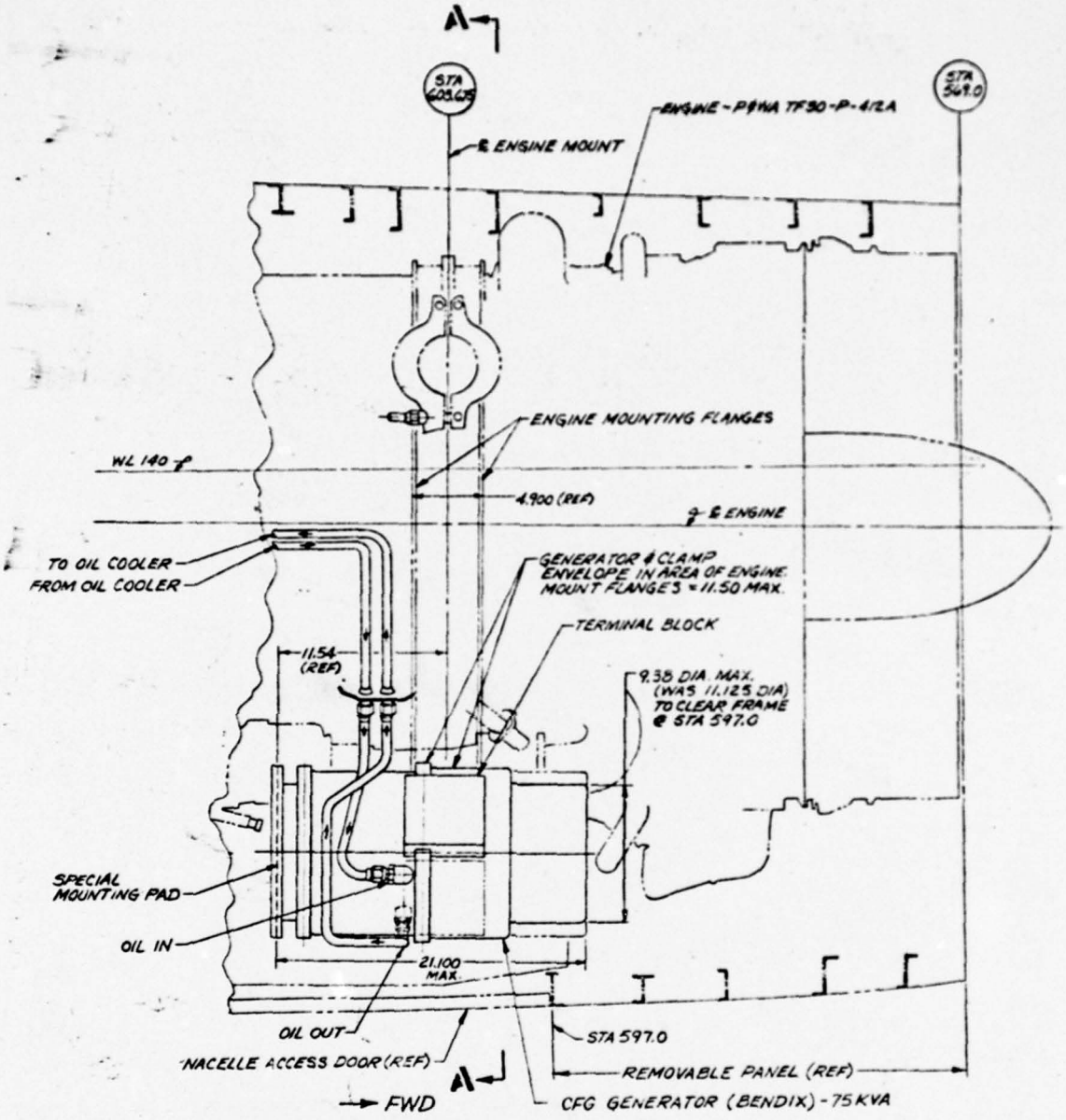
The study also indicated there should be no significant difference in size or efficiency for 1:2 of 1:3 speed ratios. However, if the minimum input speed is increased to 4100 rpm, the weight might be decreased by about 0.5 lb.

4.1.3.3 Vehicle Integration and Recommended Configuration

VSCF/CFG- F-14A integration studies were conducted in the following areas:

- Installing a CFG system in place of the IDG utilizing the present oil cooling system
- Installing a VSCF generator and cycloconverter utilizing an oil-cooling concept
- Installing an air-cooled cycloconverter.

The Bendix - CFG design was selected for the installation study because it is the only proposed system that may be cooled by the existing IDG oil cooler. The Bendix CFG installation is shown in Fig. 4-22 and illustrates several minor interference areas. However, this design represents a CFG proposed for the Boeing 727/737 airplanes and can easily be modified for the F-14A installation (i.e., relocate terminal block and reduce the integral electronics package to 9.38 in. diameter). The oil lines from the generator to the engine bracket will also need to be replaced. Aside from these minor changes, the CFG installation comes very close to being a one for one change to the present IDG system.



SIDE VIEW - R.H. ENGINE INSTL - LOOKING INBD

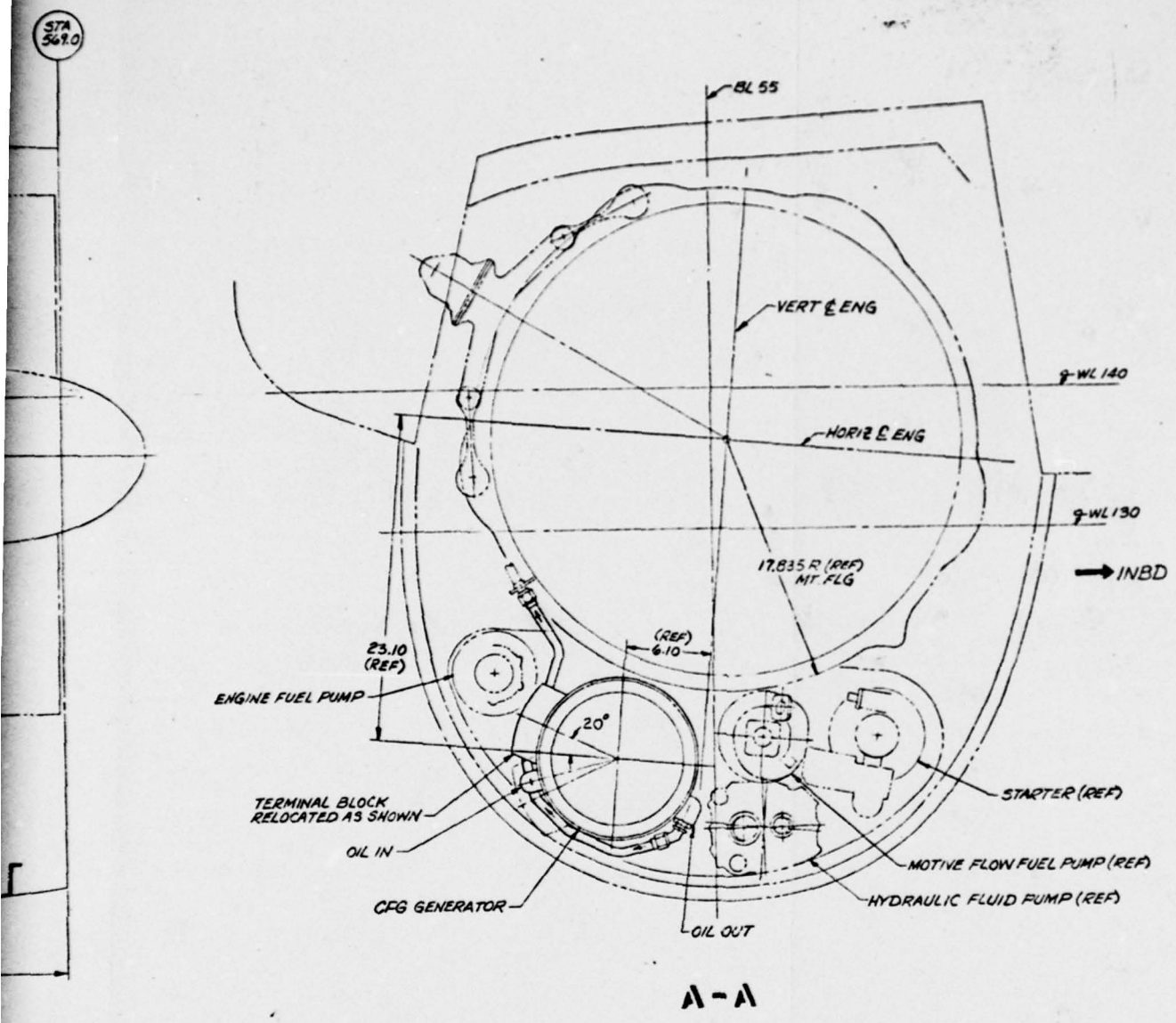


Figure 4-22. CFG Installation

The only unoccupied regions of the F-14A capable of holding 24 in. long cycloconverters are the aft sponson regions. These regions are located at the left and right outboard surfaces of the fuselage, just forward of the horizontal stabilizer actuators. Each sponson is roughly trapezoidal in cross section and can accept only one $7\frac{1}{2}$ in. x 13 in. converter cross section. Each sponson region extends 35 in. forward of the bulkhead at STA 702.5. Hence, only one 24 in. long converter can fit within each sponson region. The maximum temperature of the sponson region is about 350°F. For installation of the cycloconverters, access must be through the air passage. Because the skin is permanently attached over the sponson regions at present, an access panel will have to be made on both sides of the aircraft. This will require redesign of 5 structural frames (per side) within the sponson region. It should be noted that the sponson regions have been designated for two other ECP's which are currently awaiting approval. Should these be approved, the sponsons will be unavailable for the AAES cycloconverters on a production aircraft unless additional installation requirements are considered.

The installation drawing of the near-term HVDC system (Fig. 4-30) consisting of a generator and a PCU, can be considered illustrative of the GE VSCF installation. The proposed Westinghouse cycloconverter requires air cooling and its installation in the aft sponson area would be similar to the installation of the SOSTEL processor shown in Fig. 4-109.

The Bendix CFG system has been selected for the baseline PGS prototype design for the following reasons:

- Thermal cooling compatibility with the present IDG cooling loop
- "Best" design for vehicle integration minimizing changes to present installation
- The CFG design represents a generator and converter concept that could lead to the development of a HVDC system.

4.1.4 CFG Specification Comments

Specification MIL-E-23001A (AS) "Electric Generating System, Variable Speed

Constant Frequency - General Specification for" was reviewed by the Bendix Corporation for compatibility with their proposed CFG design. Their comments to this specification are summarized in Appendix C.

4.1.5 High Voltage Direct-Current (HVDC)

A similar, but smaller, effort than the VSCF task was pursued in this area. An HVDC data package was submitted to the suppliers requesting data on both an HVDC generator and a power conditioning unit to supply 400-cycle a-c for selected equipments.

Installation contraints, service conditions, EMI, control, cooling and performance requirements were based on the present F-14A IDG specifications. In addition, the following NADC documents were specified for use as technical references:

- "NADC-VT-TS-7502 Generator System, 270V, Direct Current, Aircraft, Engine Driven, General Specification for"
- "NADC-VT-TS-7500 Power Conditioner Unit, Aircraft, 115/200 volt, 3-phase, 400 Hz, General Specification for".

Seven companies were contacted for data, and responses were received from four: Bendix, GE, Sundstrand and Westinghouse. The three other companies (Delco Electronics, Lear-Siegler and Precise Power) chose not to submit HVDC data. Table 4-8 summarizes the significant characteristics and design approaches selected by the various suppliers. The GE approach is described in the following section and illustrates the typical design(s) being proposed for the HVDC system except for one item. GE is proposing an existing separate gearbox, whereas Bendix and Sundstrand proposed an integral gear design.

4.1.5.1 GE - HVDC Generator Design Approach

The HVDC electrical generating system consists of a brushless 270-vdc generator and a generator control unit which contains all the necessary system protective, circuits and logic. An HVDC system block diagram is shown in Fig. 4-23.

TABLE 4-8. HVDC GENERATOR DESIGN CHARACTERISTICS COMPARISONS

Design	Bendix	G.E.	Sundstrand	Westinghouse
Main AC Generator				
No. of Phases			6	5
Nominal Voltage, L-N				116V
Frequency, Hz				378 to 756
Speed Range, rpm	7560-15,120	10,000-20,000	7560-15,120	7560-15120
Cooling (Oil Spray)				
Oil Flow (GPM)	4	-----	----	4.5
Oil Inlet Temp (Max. Cont.), °F	300	300	250	300
Mech./Installation Data				
Generator				
Weight, lb	73	132	90	118
Overhung Moment, lb-in.	700	----	900	1050
Basic Dia., in.	8.5	10	11.3	8.25
Overall Length, in.	21.0	19.25	20.5	22
Generator Control Unit				
Weight, lb	.3	5	5	6
Volume, cubic in.	125	216	207	250
Size, in.	5 x 5 x 3		6 x 5.8 x 6	6 x 6 x 7
Reliability MTBF Est				
Generator, hr	9200	1672	8460	9700
GCU, hr	12600	18812	24000	25000
1 Channel, hr	5300	1540	6150	7000

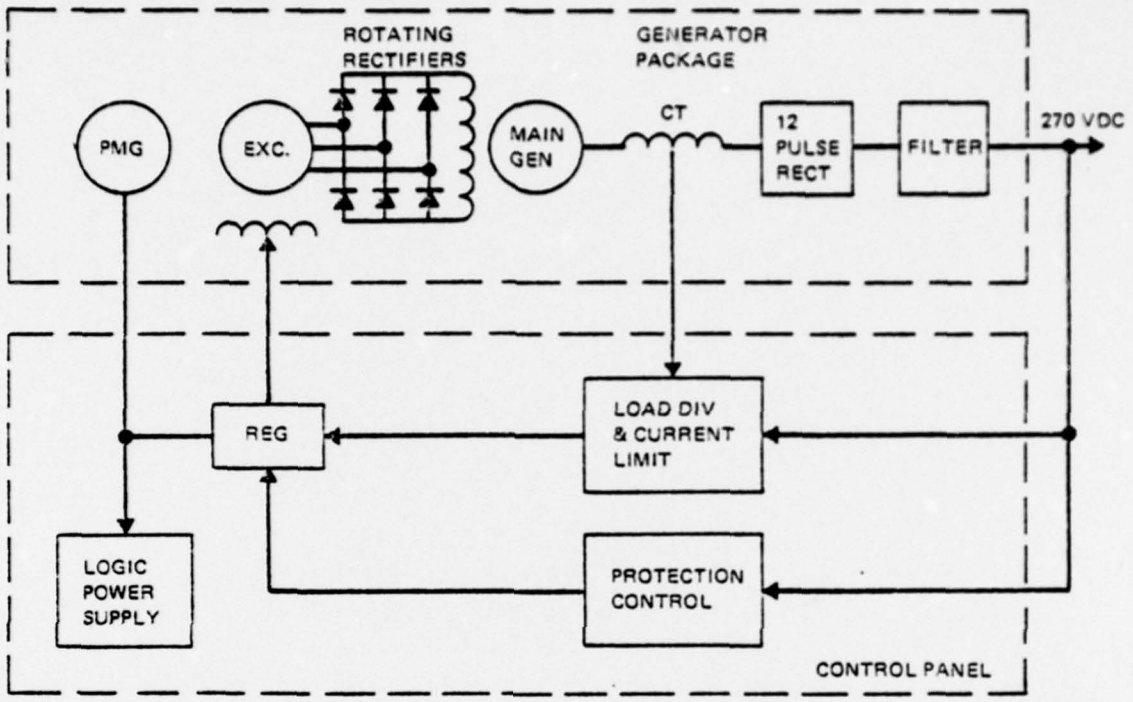


Figure 4-23. G.E. HVDC System Block Diagram

The baseline HVDC generator is a brushless machine which contains a permanent magnet generator, exciter, main generator, rectifier, output filter and gearbox. The baseline generator frame is made of cast aluminum. Vanadium permendur steel laminations are used in the main generator and exciter to reduce weight and increase efficiency. The windings are impregnated with a polymide and epoxide insulation system to withstand the oil and temperature environment.

Control terminations are made with multiple pin connectors. Power connections are made through protected studs mounted in a terminal block.

Spray oil cooling of the electromagnetics is employed using MIL-L-7808 or MIL-L-23699 oil which passes through large slots, rather than nozzles, to prevent clogging. This oil also lubricates the bearings and cools the output power rectifiers.

A dip-brazed aluminum chassis forms the basic structure for the convection air cooled generator control unit. Removable printed circuit boards contain system regulation and protection circuitry. Sensing and excitation leads are brought into the generator control unit via a connector.

The HVDC generator design selected as a baseline for the F-14A study is similar to generator designs currently being supplied to the Air Force and the Navy with the exception that the generator oil pump housing will be modified to package the output rectifiers and interphase transformer.

Approximate generator control unit size and weight are 6 in. x 6 in. x 6 in. and 5 lb, respectively. A current sensor for feeder fault protection will weigh approximately 1 lb.

The gearbox used on the 3700 to 7400 rpm baseline pad will be an inline type with a 2.7:1 step-up ratio. An internal drive gear will mesh with the three equally spaced idler gears which in turn mesh with the driven rotor gear. The internal gear will be flexibly mounted on the input shaft so that the reactions of the three idler gears may be equalized, compensating for the small errors that may be present. With this compensation, the only bearings to carry the gear reactions will be

the idler bearings. The efficiency of the HVDC generator is shown in Fig. 4-24. The resulting losses of the generator are as follows:

Load, pu	Losses, kw
.5	12.2
.75	13
1.00	14.5
1.25	16.1

In addition, the estimated efficiencies of all HVDC designs are compared in Table 4-9. Oil from the heat exchanger will be directed through contained oil passages in the output rectifier located on the oil pump housing. The output rectifiers will operate satisfactorily in 300°F oil under steady state conditions with intermittent operation at oil temperatures to 325°F at rated load if no overloads are applied during the temperature excursion.

A 12-pulse rectifier circuit is used to reduce the ripple voltage and the filter weight. Two connections have been used. The first is the series connection of two three-phase bridges as shown in Fig. 4-25a. The second is the parallel connection shown in Fig. 4-25b. The parallel connection has one-half the rectifier power loss but requires an interphase transformer having more weight than the simple filter reactor used in the series connection. Both connections have equivalent electrical performance.

Each three-phase bridge is supplied from three-phase windings on the generator. The three-phase windings are displaced 30 electrical degrees to produce 12-pulse ripple at the output of the rectifier. The RMS value of the ripple is only 2.9 volts assuming a sine wave generator and no commutation notches. Actually, the ripple has a higher value than this caused by the commutation process and generator harmonics. These will be minimized by designing a generator with low subtransient reactance and relatively low harmonics without adding significant generator weight. The design is a compromise between generator weight for low harmonics and the filter weight required to reduce the ripple voltage.

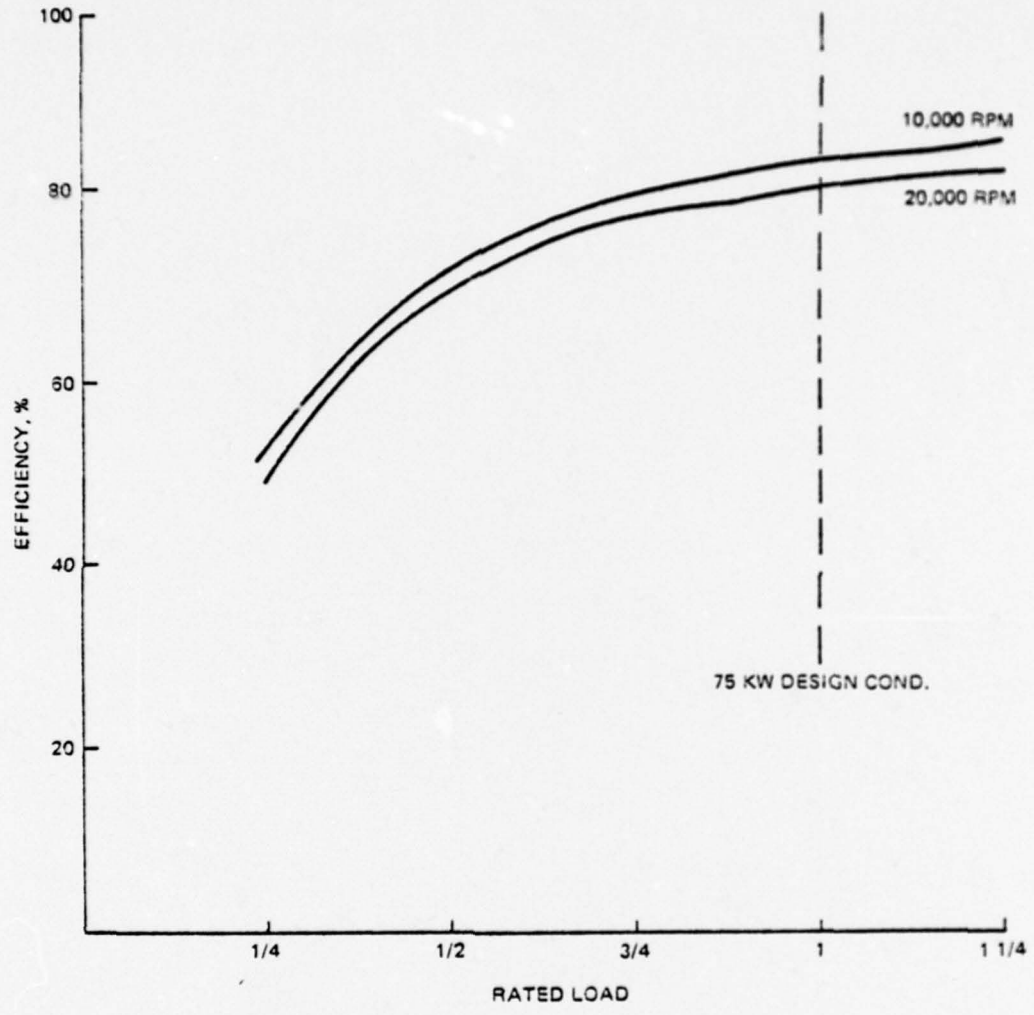
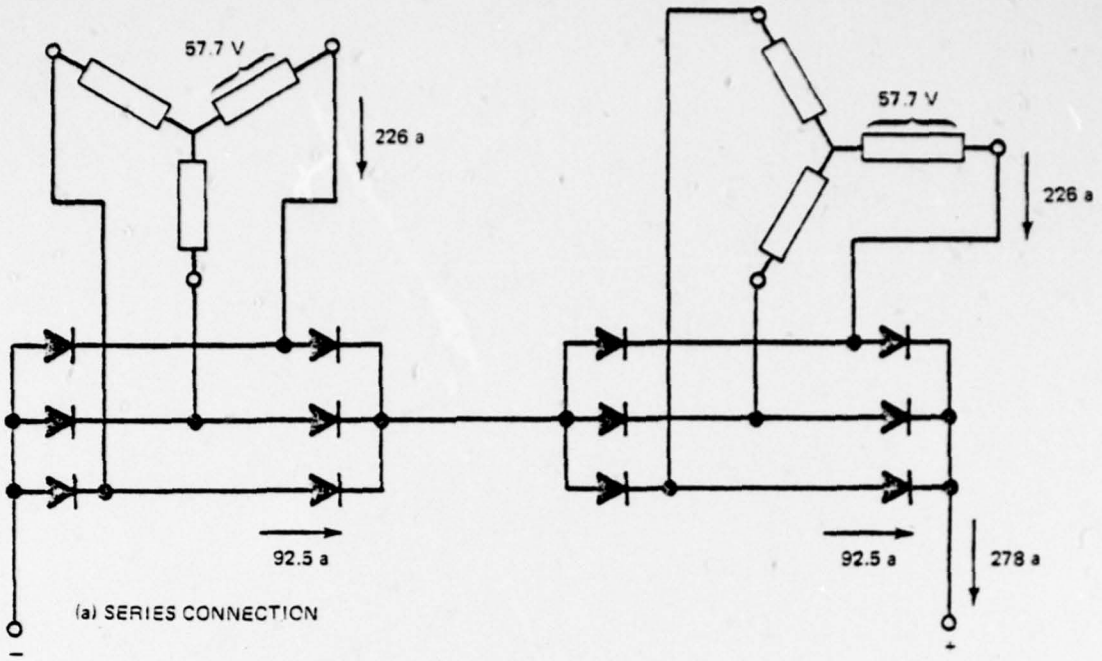


Figure 4-24. G. E. HVDC Generator Efficiency

TABLE 4-9. HVDC GENERATOR EFFICIENCY COMPARISON

Rates Load	Bendix 7560/15120 rpm	Generator G.E. 10,000/20,000 rpm	Efficiencies Sundstrand 7560/15120 rpm	Westinghouse 7560/15120 rpm
1/2 (37.5 kw)	87/86	73/70.3	84/80	75/70.7
3/4 (56.25 kw)	88/87	80/78	84.5/81.5	79.2/76.6
1 (75 kw)	89/88	84/81	84.2/81.5	80.8/79.7
1 1/2 (93.75 kw)	88/87	85.5/82	83/81	80.8/81



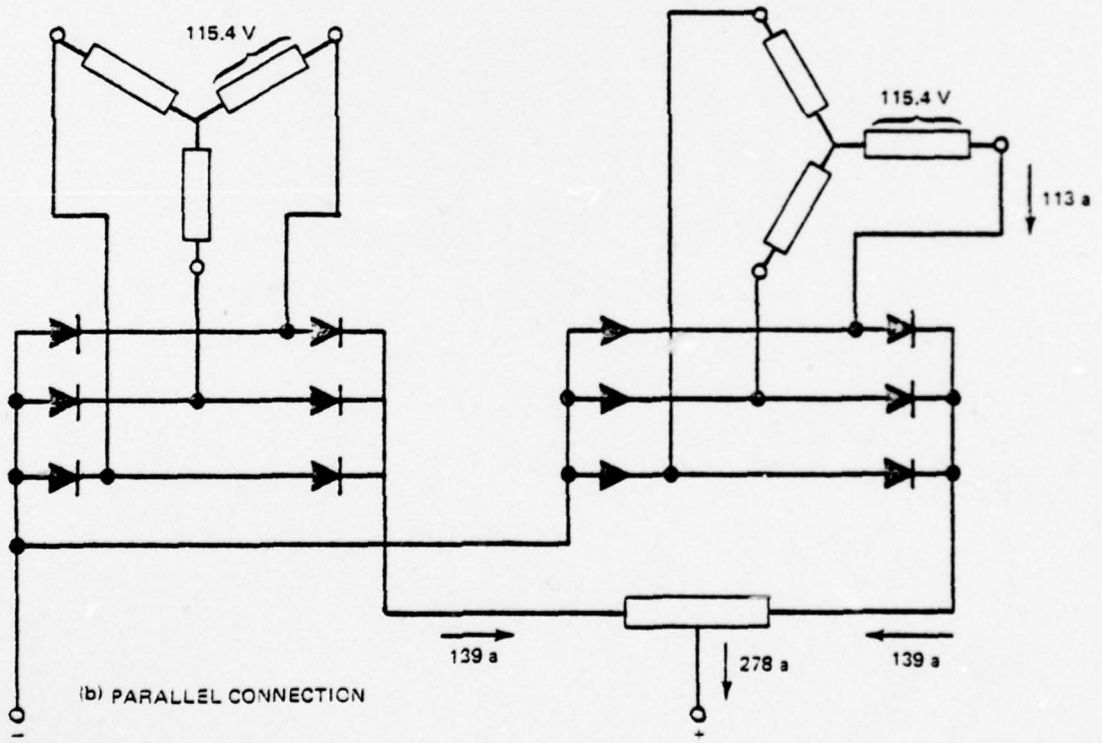


Figure 4-25. Twelve-Pulse Rectifier Connections Using Three Phase Bridges

The six-pulse rectifier circuit is not used because it has four times as much rms ripple at half the ripple frequency and requires eight times more filtering than the 12-pulse rectifier. The 24-pulse rectifier circuit is not used because it requires 24 rectifiers without much improvement in ripple reduction. The 12-pulse rectifier is the best compromise for low weight and cost.

The generator control unit (GCU) will have the following control and protective features:

- Voltage regulation
- Overvoltage
- Undervoltage
- Feeder fault and generator fault protection (provision for)
- Generator failures
- Anticycling
- Line (bus) contactor control
- Pilots manual control switch
- Equalizer circuit for parallel operation.

The generator control unit includes the following functions:

- Voltage regulation
- Equalizer circuit for parallel operation
- Line contactor control
- Protection.

4.1.5.2 Parametric Power Conditioning Unit (PCU) Data

The near-term application of HVDC to the F-14A aircraft requires conversion of primary 270 vdc power to 115/208-volt, 3-phase 400-Hz a-c power for selected equipments. Parametric data were received from Bendix, GE, Sundstrand and Westinghouse and is summarized in Fig. 4-26.

The proposed PCU characteristics vary widely according to the manufacturers assumed design requirements which are described in the following paragraphs.

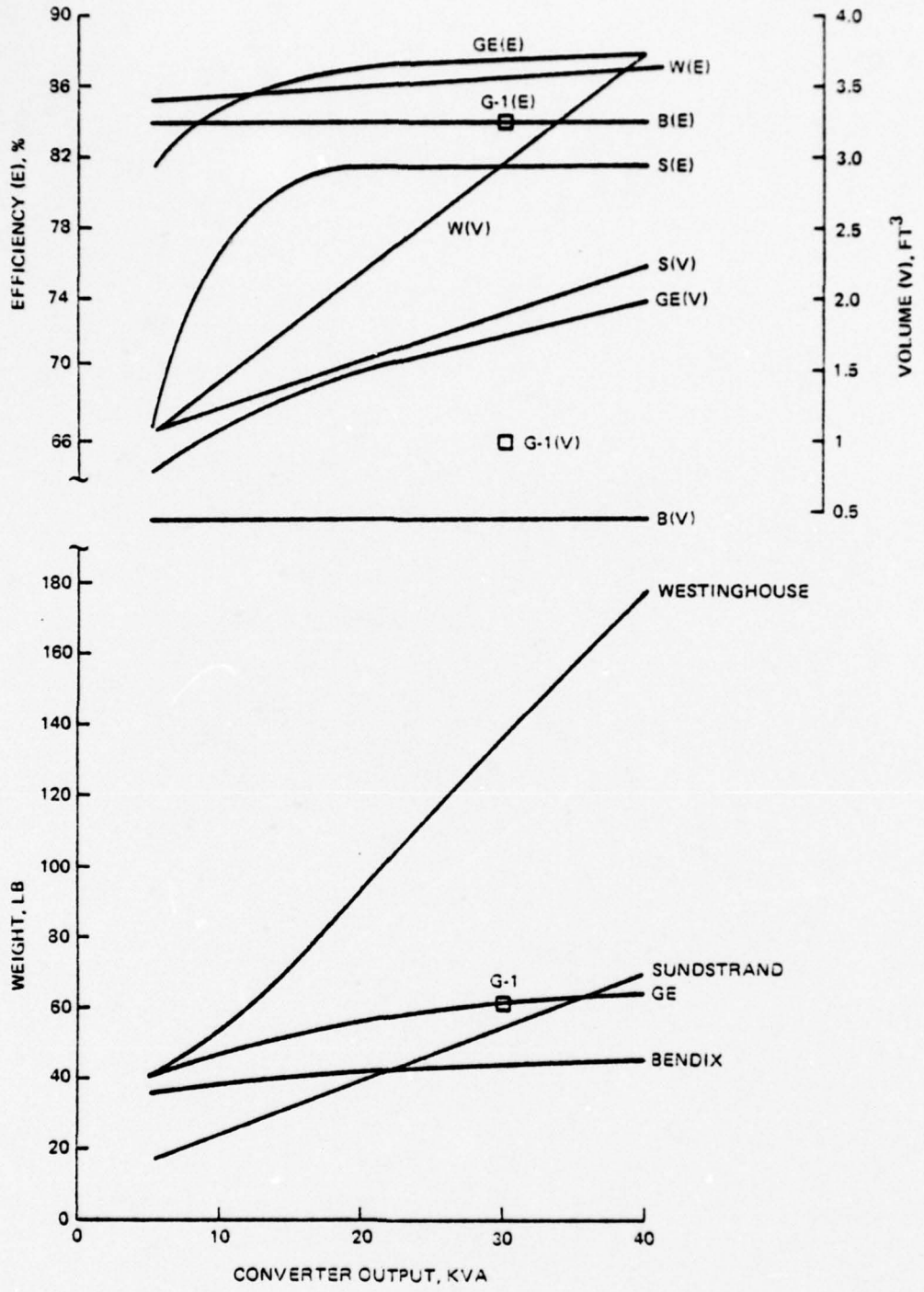


Figure 4-26. Power Conditioning Unit (270 VDC - 115 VAC) Weight, Efficiency and Volume Comparison

- Bendix - Assuming the size of the converter would be less than 750 cu in. for all of the kva ratings from 5 to 40 kva, the number and size of the electronic components would be the same. The major component that would change as a function of rating is the output transformer. The change in transformer would not effect a significant change in package size or weight. The efficiency of the converter would be much lower than the CFG concept. The addition of a series regulator and the d-c to d-c converter are the contributing factors to lower efficiency. The PCU is designed to meet the EMI requirements of MIL-STD-461 class IIIB

- Sundstrand - Data are based on components featuring conventional electronics, resistors, capacitors, transistors, diodes and SCR's. The most temperature-critical components are the SCR's. The SCR case temperature must be limited to 160°F maximum to maintain an adequate ΔT for transferring thermal energy out of the SCR at rated load. SCR failures can be expected to increase dramatically beyond this point. Fast switching electrical devices always generate large amounts of electrical noise. Initial estimates for a 30-kva-rated PCU indicate that the conducted noise could be as much as 60 db above the limits of MIL-I-6181. This level will be extremely difficult to filter and may impose a severe weight penalty. Additionally, the SCR's will be very susceptible to misfiring due not only to the conducted noise but also to radiated noise received from other equipments on the aircraft. Protecting the PCU from noise, both internally and externally generated, is a critical requirement and would require an extensive development program.

- Westinghouse - The data are based on SCR type inverters utilizing harmonic cancellation for waveform control. Voltage regulation is accomplished within the inverter using pulse width modulating controllers. The data are based on units capable of supplying 150% overloads for 5 min and 200% short circuit current for 5 sec.

These inverters reflect a higher weight per kva ratio than the inverter dis-

cussed for the VSCF system because the HVDC systems require different type inverters. In the VSCF system the generator is dedicated to the inverter, hence, voltage regulation, current limit control, and transient control can be accomplished by controlling the generator excitation. However, the inverters used in the HVDC system must preserve the quality of the 270-volt bus. This requires that the inverter provide all load regulation functions as well as provide for current limiting and other self protective features. Control power for the inverter must also be derived from the 270-volt bus. These features plus the fact that each inverter pole must have the ability to commutate during any portion of the output waveform results in a larger and heavier inverter approach than the inverter of the VSCF system. In addition, because each inverter pole must switch more often to provide for a-c bus voltage regulation, the efficiency of the HVDC inverters is lower.

4.1.5.3 Near Term HVDC Load Considerations

The F-14A utilization equipment loads were reviewed to develop a preliminary estimate of the a-c and d-c power requirements for a HVDC system. Table 4-10 compares the present system load requirements (in the cruise combat mode) to a hypothetical HVDC system. The major assumptions used in generating the HVDC requirements are (1) motor loads above 1 kva require 115 vac and (2) avionic loads will utilize the 270-vdc input. As illustrated in Table 4-10, 19 kva would be required to operate the motor loads.

However, this is not the maximum sizing condition for a-c motor loads, as it does not contain the necessary power for operating the back-up flight control power module. This motor is activated in an emergency condition after losing both main hydraulic power supply systems. Table 4-11 presents the a-c motor loads for three emergency return conditions.

The 27 kva would be required to satisfy the aircraft's motor loads during the evasive maneuvering condition. Therefore, for preliminary sizing purposes, a 30-kva power conditioning unit would be required for a near-term HVDC system.

F-14A AND NEAR-TERM HVDC AAES LOAD REQUIREMENT COMPARISON

(Cruise Combat Mode - 3 Phoenix & 3 Sparrow & 2 Sidewinder Weapon Mix)

	F-14A		Near Term HVDC AAES CONFIGURATION		
Equip. Category	115 vac	28 vdc	115 vac	270 vdc	28 vdc
Heaters	4.62			4.62	
Lights	0.1		0.1		
Motors	18.677		18.5	0.2	
Avionics	43.6			43.6	
28 vdc		2.6 kw			2.6 kw
TOTALS	67 kva*	3.5 kva*	18.6 kva	48.42Kva	2.6 kw

*A-C Power converted to 28 vdc

TABLE 4-11. F-14A 115-VAC MOTOR LOAD REQUIREMENTS

Equipment Identification	Electric Load Requirement, kva	Emergency Return Condition		
		Cruise	Evasive Maneuvering	Landing
TACAN Blower	.0173	R	R	R
AWG-9 Cooling Pump	2.898	R	R	NR
AWG-9 Antenna Drive	2.775	R	R	NR
Phoenix Cooling Pump	3.171	NR	NR	NR
Outboard Spoiler Pump	9.000	R	R	R
Back-Up Flight Control				
Lo-Speed	7.557	R	NR	NR
Hi-Speed	11.479	NR	R	R
Total Load kva		23.003	27.139	21.512

R - Required
NR - Not required

4.1.5.4 Vehicle Integration Studies

4.1.5.4.1 Thermal Analysis - Thermal analyses were performed in integrating the proposed 75-kw HVDC generator and the near term 30-kva PCU into the existing IDG oil cooling loop. The Bendix and Sundstrand units were selected as representing typical configurations. The results are summarized in Table 4-12 and indicate that of the two systems studied, the Bendix configuration's heat rejection requirements can be met by the present IDG oil cooler capability.

The Sundstrand PCU requires the cooling oil to enter at 160°F maximum. The PCU utilizes only 18.6 kva (62% of 30-kva-rated capacity) to operate in conjunction with a 75 kw generator at 80% maximum engine speed. The efficiency of the PCU at this load is 82%. The generator and gearbox have an efficiency rating of 81.5% at full load. The total rejected heat load of 1135 Btu/min exceeds the capacity of the IDG oil cooler. This is illustrated in Fig. 4-27 which depicts the oil supply temperature as a function of heat removed by the IDG Cooler and flow rate.

In comparison, the Bendix PCU will accept oil at a maximum inlet temperature of 185°F. The efficiency ratings for the PCU and generator with gearbox at the same load conditions as specified above are 86% and 88%, respectively. The total rejected heat load is only 734 Btu/min and the existing IDG oil cooler has the capacity to remove this heat and return the cooling oil to the PCU at a temperature below 185°F. The IDG cooling loop performance for the Bendix HVDC system is shown in Fig. 4-28.

4.1.5.4.2 Engine Pad Interface Considerations - HVDC generator designs for the F-14A have assumed engine driven input speeds between 3700 to 7400 rpm (turn down ratio (TDR) = 2). Subsection 4.1.3.2 presented a comparison of the actual speeds for the present TF30-P-412 engine and the speeds currently being considered by P&WA for the F401 (Rev) remote gearbox. Comparing maximum overspeed to minimum idle (at -60°F) the TDR's are 1.73 and 1.62, respectively. Fig. 4-29 compares these lower TDR's to an estimated generator weight reduction based on GE and Westinghouse data. Seven to 11% generator weight reductions may be possible if realistic/demonstrated TDR's are specified as engine accessory pad speeds.

TABLE 4-12. HVDC SYSTEM OIL SUPPLY TEMPERATURE VS. OIL FLOW

System	Supplier	Heat Rejection Btu/Min	Max. Allowable Oil Temp , °F	Oil Flow, gpm	Oil Supply Temp, °F
1 75 kw Gen + 1 30 kva PCU	Bendix	754	185	4	154
				5	156
1 75 kw Gen + 1 30 kva PCU	Sundstrand	1135	160	3	206
				4	233
				5	237

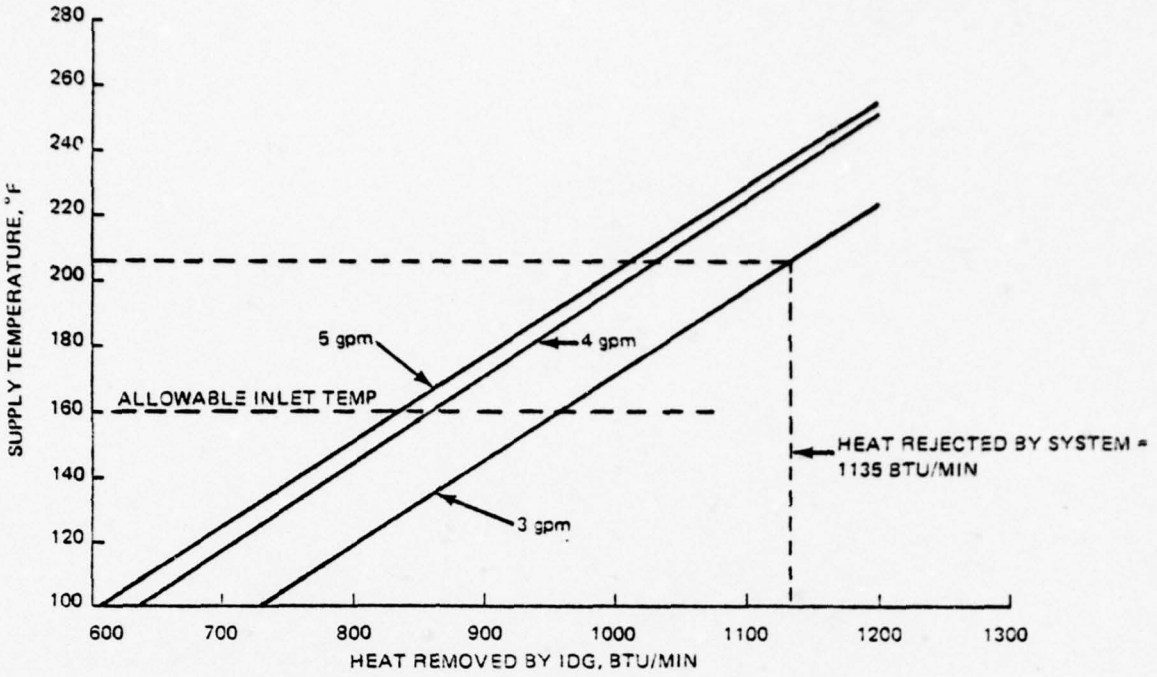


Figure 4-27. Oil Supply Temperature as Function of Heat Removed by IDG Cooler and Flow Rate for Sundstrand HVDC System

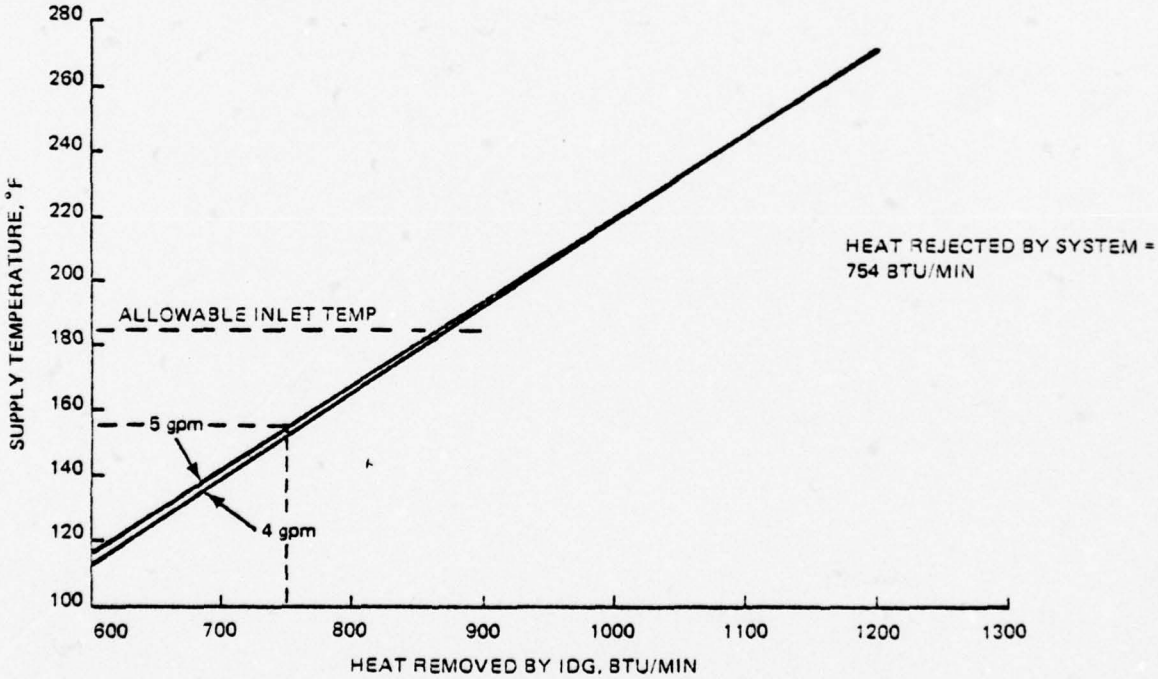


Figure 4-28. Oil Supply Temperature As Function of Heat Removed by IDG Cooler and Flow Rate for Bendix HVDC System

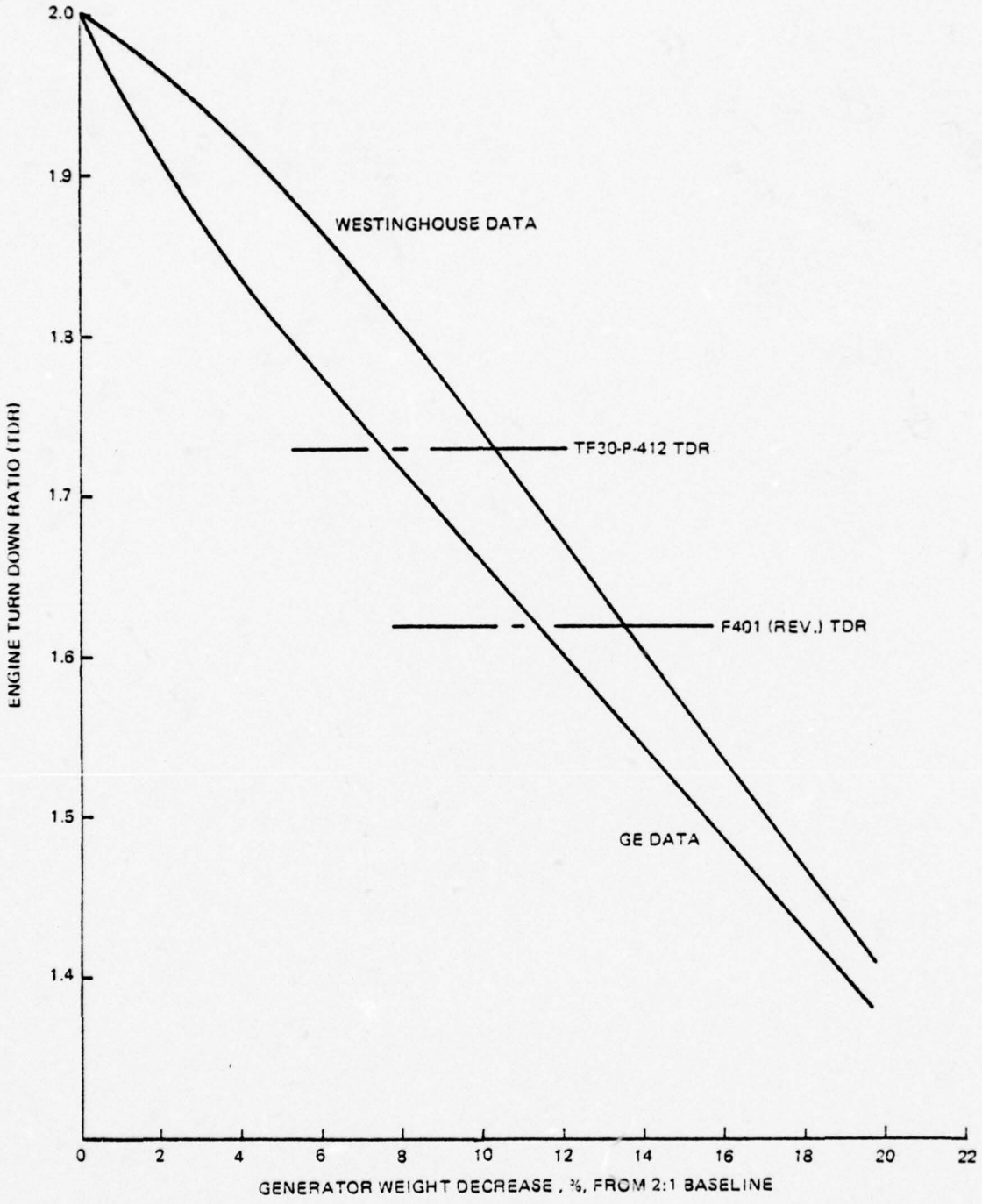


Figure 4-29. HVDC Generator Weight Vs. Engine Turn Down Ratio

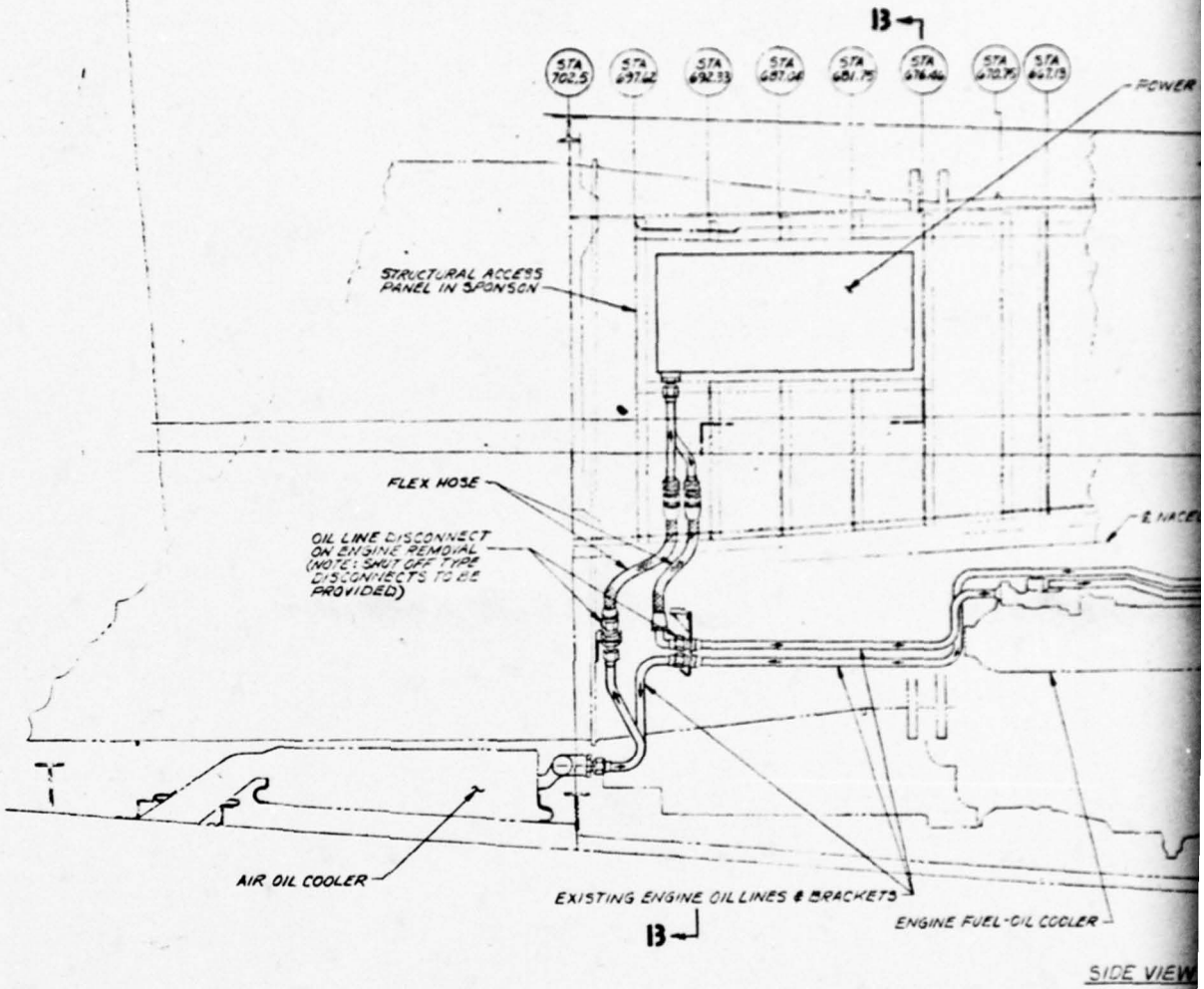
4.1.5.4.3 Vehicle Installation - HVDC - F-14A installation studies were conducted and Fig. 4-30 illustrates the Bendix HVDC generator and PCU installed in the aft sponson area. The HVDC generator fits on the existing IDG pad without problem. The present oil-in and oil-out fittings are shown, and the present oil line run to the oil cooler is satisfactory. The oil line leaving the oil cooler must be broken, and flexible lines added to and from the power conditioning unit, which is located in the aft sponson area. These flexible lines must be disconnected before engine removal. Valve type disconnects are indicated in order to prevent oil leakage. The generator installation on the engine pad and location of the PCU indicate that added feeder cable line runs will be necessary for the near-term HVDC applications.

4.1.5.5 Recommended Conceptual Approach

An all HVDC system probably cannot be implemented in the near term (1981-83) because the necessary power generation and using equipment technology developments require time and money beyond the resources expected to be available. The practical approach in initiating the development of HVDC for the F-14A is guided primarily by the utilization equipment requirements. To develop this practical configuration, we have assumed that the avionics power supplies could be converted to HVDC input stages but the large motors would remain 115-vac powered. As discussed in Subsection 4.1.5.3, a 75-kw HVDC generator and 30-kva PCU would provide the proper mix of a-c and d-c power for the near-term HVDC application and the preliminary layout is shown in Fig. 4-30.

4.1.5.6 HVDC Problem/Study Areas

The subsequent Subsections identify HVDC-PGS equipment and system problem/study areas which must be examined prior to the implementation of an HVDC system in a production aircraft. These tasks require the coordinated efforts of the equipment manufacturer, the airframe manufacturer and the NAVY.


B
STA 702.5
STA 697.42
STA 692.33
STA 687.04
STA 681.75
STA 676.46
STA 670.75
STA 667.13
POWER
STRUCTURAL ACCESS PANEL IN SPONSON
FLEX HOSE
OIL LINE DISCONNECT ON ENGINE REMOVAL (NOTE: SHUT OFF TYPE DISCONNECTS TO BE PROVIDED)
AIR OIL COOLER
EXISTING ENGINE OIL LINES & BRACKETS
ENGINE FUEL-OIL COOLER
B

SIDE VIEW

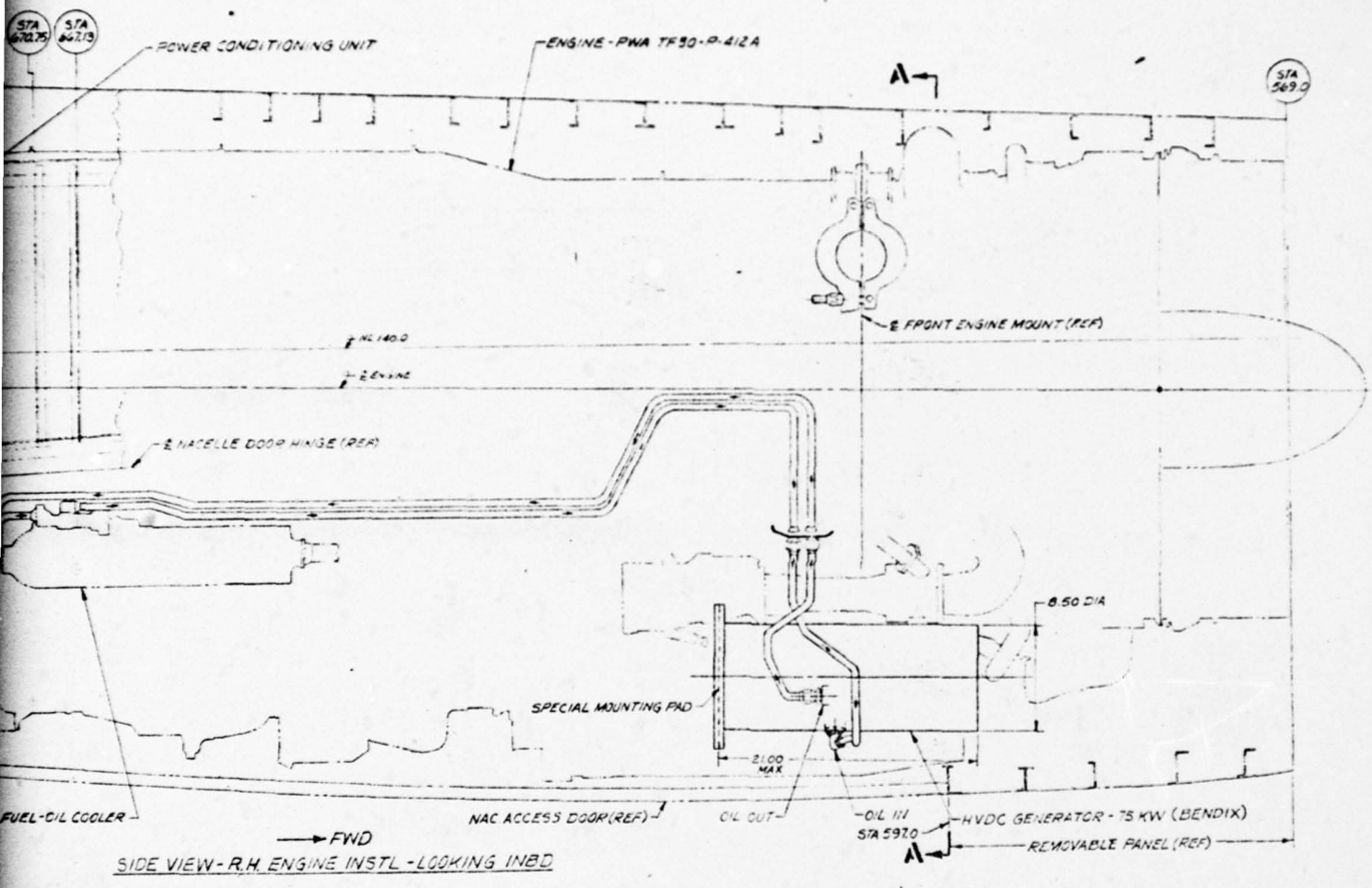
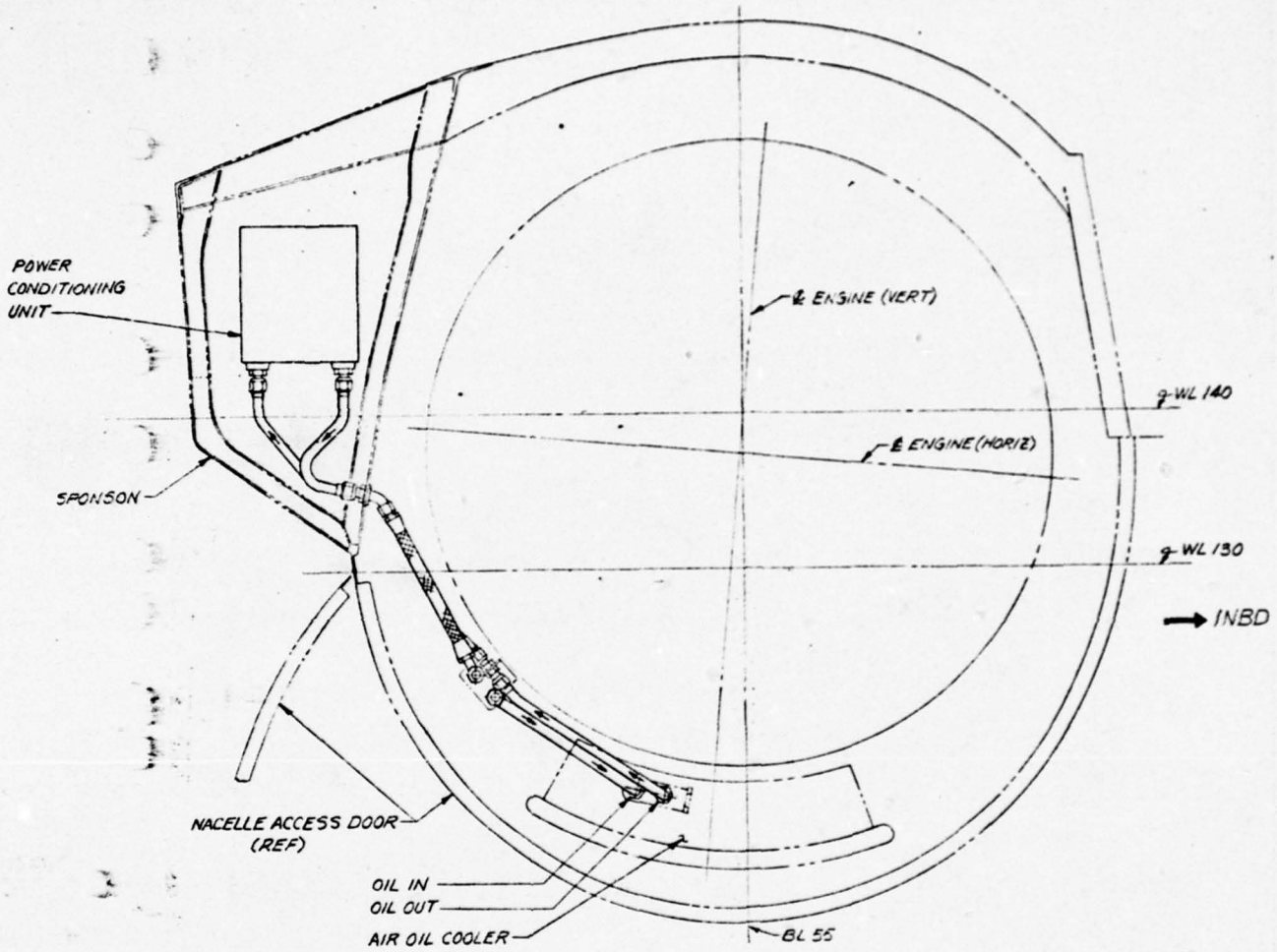


Figure 4-30. HVDC/PCU Installation (Sheet 1 of 2)


POWER
CONDITIONING
UNIT
SPONSON
℄ ENGINE (VERT)
℄ WL 140
℄ ENGINE (HORIZ)
℄ WL 130
INBD
NACELLE ACCESS DOOR
(REF)
OIL IN
OIL OUT
AIR OIL COOLER
BL 55

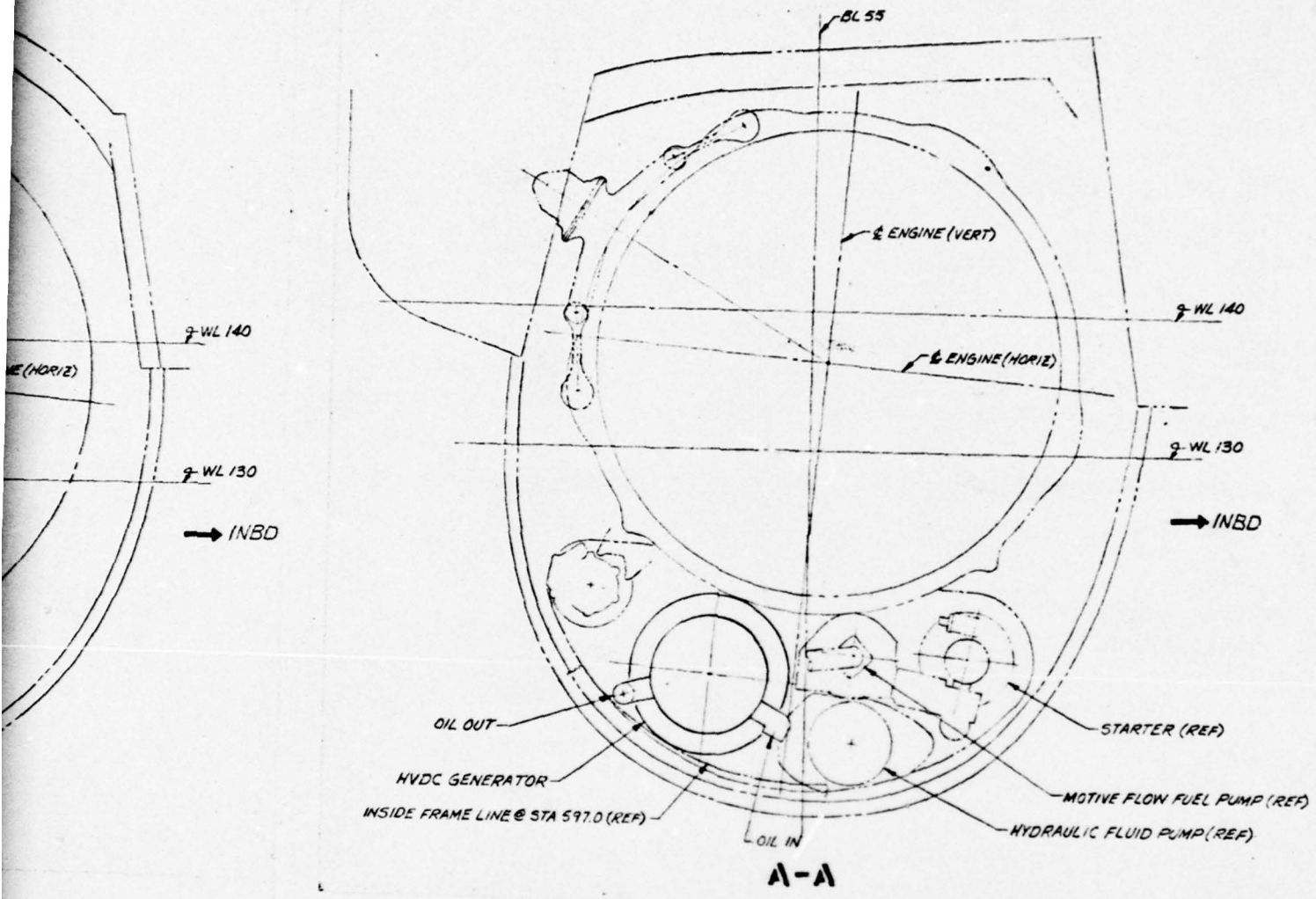


Figure 4-30. HVDC/PCU Installation (Sheet 2 of 2)

4.1.5.6.1 Primary Power Generation

- Degree of ripple/spikes resulting from rectification
- Location of filter (internal or external) and need for shielded power cables between generator and filter
- Effect of filter power factor on generator sizing
- Tradeoff between rectifier-filter technique and use of force - commutated SCR's or SCS's (internal or external)
- Effect or poor generator transient response on design of power converters and utilization equipment
- Fail-safe GCU circuitry required to de-energize generator in event of regulator short (high ceiling voltage), overcurrent or whenever main line contactor (an SCR) must be opened to interrupt high current.
- Size, weight, reliability penalties for APU and EPU generators which normally operate at constant speed
- Feasibility of electric starting systems
- Power quality and interface/protection requirements for ground power
- Overload design requirements accounting for possible fusing in filters and solid state power controllers.

4.1.5.6.2 Power Distribution & Control

- Techniques and devices for switching high current HVDC
- Fault-sensing and power interruption required for personnel safety
- Significance of wire weight savings for small (typical Naval) aircraft
- Voltage regulation techniques and effect on design of power converters and utilization equipment.

4.1.5.6.3 Utilization Systems

- Feasibility of standardizing load function voltages
- Penalties and advantages of using HVDC - d-c converters as input stages to user equipment
- Trade off converter designs using HVDC and double-voltage WFAC
- Feasibility of developing brushless HVDC motors competitive with present induction motors - practical size limits
- Comparison of inverter/motor requirements for HVDC and WFAC systems.
- Define specific power forms best used in each load function and best way of generating/converting primary power to satisfy all load requirements
- Define practical near-future limits on solid state devices and relate these to actual converter/system performance
- Feasibility of "centralizing" power conversion stages in an actual installation-define penalties associated with requirement to distribute load conversion/control centers in a practical application
- Design requirements to isolate user loads imposed on "centralized" converters-comparison with individaual load conversion
- Overall subsystem interactive and filtering requirements accounting for generator ripple/spikes, converter, control and load switching need a good systems spec
- Define how and when various user equipments will be redesigned to use HVDC, how equipment will be introduced in the field, supply/support logistics and total cost for the conversion.

4.1.5.6.4 Installation

- Impact of HVDC system integration - equipment location, cooling requirements,

circuit protection and compromises required in central vs distributed power conversion/control philosophy.

4.6.5.6.5 System

- Dynamic performance and stability analysis of HVDC system
- Compare HVDC with double-voltage WFAC system.

4.1.6 PGS Comparison

The present F-14A PGS (IDG) has been described in previous Subsections (i.e., 4.1.2). A baseline weight statement has been prepared for the present system and is compared to the recommended CFG and HVDC PGS configurations. In addition, the changes required of the supporting subsystems are also described. The overall impact of integrating the recommended PGS configurations within the F-14A is discussed in this section.

4.1.6.1 Present PGS (IDG) Configuration

The major sections of the PGS are defined as:

- Alternating - current generator
- External electrical
- Emergency electrical.

The components and assemblies comprising these sections are listed in Table 4-13 which also defines the current weight statement for the baseline PGS. Wire weights are also included in Table 4-13 for comparison with the AAES configurations.

4.1.6.2 CFG PGS Configuration

The recommended CFG configuration (Fig. 4-22) is similar to the present IDG configuration. The emergency and external electrical sections are retained in their

TABLE 4-13. F-14A POWER GENERATION SUBSYSTEM WEIGHT STATEMENT

Section	Ref. Des.	Item Nomenclature	Weight, lb
Alternating Current Generator	66A1	Voltage Regulator Control (Left)	2.7
	66A2	Voltage Regulator Control (Right)	2.7
	66A5	AC Power Sensor (Current Transformer)	2.1
	66G1	Generator- Transmission (Left)	110.7
	66G1	Generator - Transmission (Right)	110.7
	716A1	Master Generator Control Panel	2.1
			(231.0)
Emergency Electrical	67A1	Motor- Generator Control	1.5
	67G1	Motor- Generator	20.7
	67L1	Motor- Generator Solenoid Control Valve	1.3
			(23.5)
External Electrical	66A3	Ground Power Monitor	2.0
	66A4	External Power Panel	2.3
	67TR1	Transformer- Rectifier (Left)	8.8
	67TR2	Transformer- Rectifier (Right)	8.8
			(21.9)
Wiring	Power Control	Left Generator to Power Contactor	15.6
		Right Generator to Power Contactor	16.6
		External Power Panel to Power Contactor	4.2
		Gen to Volt. Reg	2.0
			(38.4)
		TOTAL PGS (IDG)	314.8

entirety as on the present aircraft. The present oil cooling loop is also retained. The slightly heavier CFG's replace the IDG's plus their associated voltage regulators.

The added control wiring necessary for synchronizing the CFG's is assumed to be equal to the removed voltage regulator control wiring. The added bus-tie contactor accounts for a small increase in the associated equipment estimate.

Overall the CFG PGS is estimated to weigh approximately 334 lb (refer to Table 4-14 for preliminary weight statement).

4.1.6.3 Near Term HVDC Configuration

The recommended near-term HVDC configuration is shown in Fig. 4-30. The external electrical section would require modification to be compatible with the PCU. The transformer-rectifiers were retained in the initial preliminary review but it appears 12 to 15 lb could be removed from this section if the 28-vdc requirement were combined in the PCU with the 115-vac requirement. The emergency section's motor generator would require design changes to satisfy the revised emergency d-c/a-c load requirements; which would correspond to the d-c/a-c requirement mix projected in Table 4-10. A preliminary weight statement (Table 4-15) indicates that a near-term HVDC PGS would weigh approximately 346 lb. This weight is approximately 10% greater than the present IDG system and represents the worst-case HVDC configuration because of the requirement for supplying 30 kva of a-c power. An optimum HVDC PGS is estimated to weigh 220 lb assuming removal of the PCU's, supporting cooling lines and AC feeder wire weights. This weight estimate provides for d-c feeder wire weight increase.

TABLE 4-14. CFG PGS WEIGHT ESTIMATE

Section	Item Nomenclature	Weight, lb
Alternating Current Generator	AC Power Sensor (Current Transformer)	2.1
	CFG (Left)	122.0
	CFG (Right)	122.0
	Master Generator Control Panel	2.1
		(248.2)
Emergency Electrical	Same as present	23.5
External Electrical	Same as present	21.9
Wiring (Power Lines)	Same as present	36.4
Wiring	Synchronization Control	2.0
Power Distribution	Bus Tie Contactor	2.0
Supporting Systems	Oil Cooling Loop (No change from baseline)	-----
	Total PGS (CFG)	334.0

TABLE 4-15. HVDC PGS WEIGHT ESTAMITE

Section	Item Nomenclature	Weight, lb
Direct Current Generator	HVDC Generator (Left)	73
	HVDC Generator (Right)	73
	Master Generator Control Panel	3
		(149)
Emergency Electrical	Motor - Generator Control	
	Motor - Generator	Modified (25)
	Motor - Generator Solenoid Control Valve	
External Electrical	Ground Power Monitor	2.0
	External Power Panel	2.5
	PCU (Left)	60.0
	PCU (Right)	60.0
		(124.5)
Wiring	DC Feeder to Contactor (shipset)	4.0
	AC Feeder [Gen to PCU to Contactor (shipset)]	33.0
	External Power Panel to Contactor	2.0
		(39)
Cooling Lines (Δ to IDG)	Additional Oil Lines plus Fitting (5' length, 4 places)	(8)
	Total PGS (HVDC)	345.5

4.2 SOSTEL

The significant aspects of the operation of a SOSTEL and conventionally equipped aircraft is compared in Fig. 4-31. The angle-of-attack (AOA) transmitter, Fig. 4-31, is the sensing probe element in the angle-of-attack system for the F-14A aircraft. This system provides angle-of-attack information to the pilot via an approach indexer and graduated AOA scale, and to the landing signal officer via the approach lights. The heater for the AOA transmitter is energized if the ORIDE (override) position on the engine/probe anti-ice switch is selected or if the AUTO position is selected and weight is not on wheels ($\overline{\text{WOW}}$). The latter condition is effected by limit switches on the left and right main landing gear. To solve the Boolean equation the present logic requires a circuit consisting of two relays (4PDT), two limit switches (4PDT), a DP3T switch, and three circuit breakers. The multiple contact devices are required if more than one Boolean equation must be solved using a single signal, since different voltages may have to be switched. Additional hardware requirements (not shown on the block diagram) include 27 connector junctions for signal and power. Moreover, the high power that flows through cockpit devices imposes additional cooling requirements, and increases the fire hazard. After an electro-mechanical configuration of the Boolean equation is implemented, the only way the equation can be altered is by rewiring the aircraft.

In b of Fig. 4-31, the SOSTEL implementation of the same function is symbolically illustrated. In this implementation, signal transducers LWOW, RWOW, ORIDE, AUTO, and OFF are sampled by the multiplexer terminals in the vicinity of the signal source. (For simplicity, all signals in b of Fig. 4-31 are shown entering one multiplexer terminal; this is not normally the case.) This information, along with the state of other signal sources, is transmitted from multiplexer terminals via the data bus to the MU (processor) as (periodically) commanded by the processor. The processor stores the state of the signals in an input memory and uses this information as input terms for the solution of its catalog of Boolean equations. The equations may have

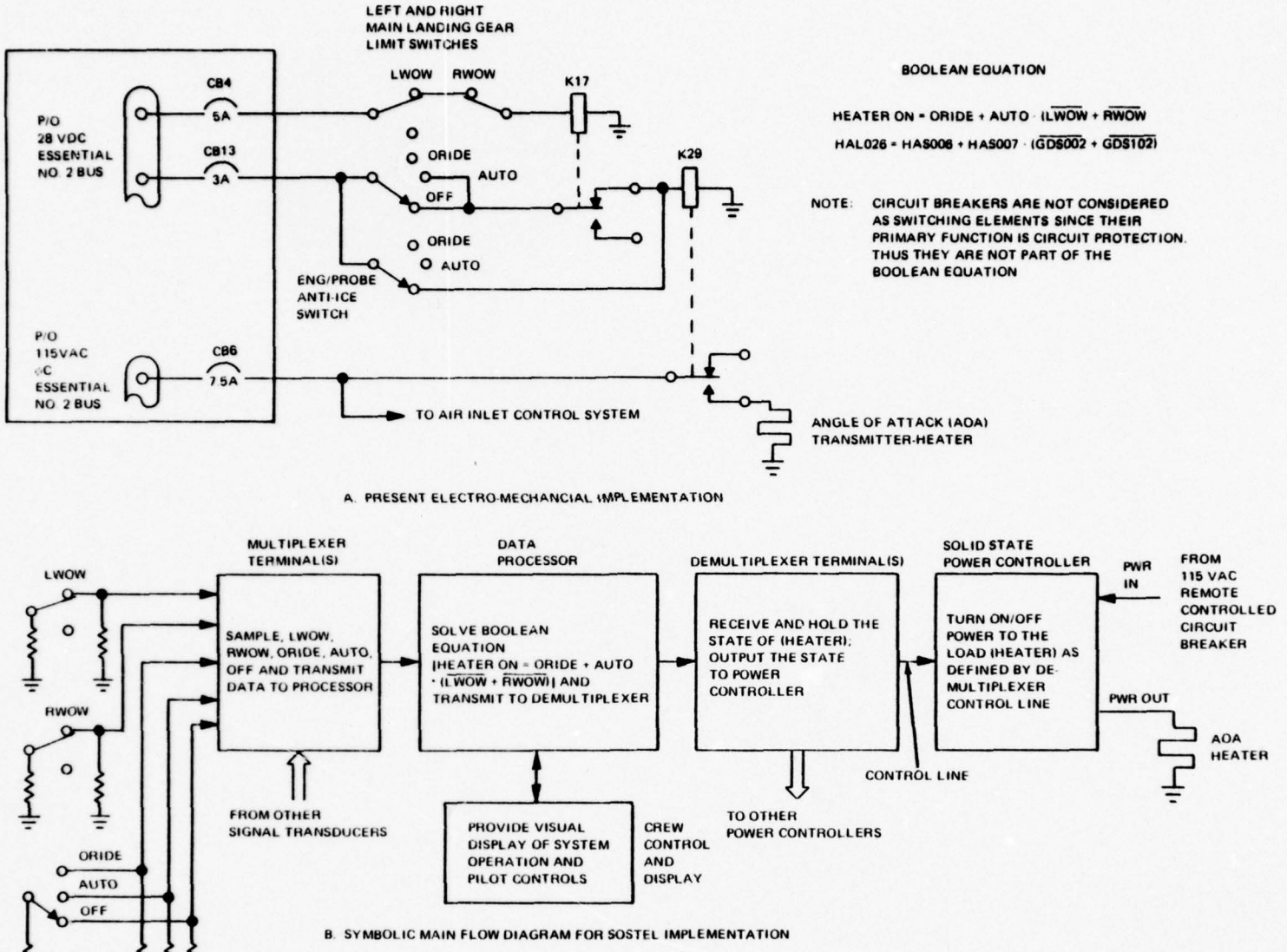


Figure 4-31. F-14 Angle-of-Attack Transmitter - Heater Control

additional constraints placed upon them by the processor program as a function of load management, flight profile, time delays, sequential operation, etc. The solution of the equation is stored in the processor output memory and is continually updated each time the equation is solved. The processor transmits this output information via the data bus to the appropriate demultiplexer terminal, where it is stored and used to provide a control signal to the solid state power controller. The power controller switches power on and off to the load (heater) as a function of the state of the control line. The controller also has the capability to "trip-out" in the case of an overload condition, and to detect normal operation relative to its state and the load requirements. The controller thus provides load protection (circuit breaker function) and switching (relay or switch function).

In the SOSTEL configuration, signal sources (transducers) are standardized to provide a switched impedance output in relation to the state of the device. This switched impedance can be implemented via solid state switches, contact switched impedances (as illustrated in a Fig. 4-31) or by external adapters to existing electronic boxes or by data terminals having appropriate user I/O's. The signal sources are sampled by the multiplexer terminal in the vicinity of the source, thereby eliminating the need to route signals throughout the aircraft to pick up additional inputs of a particular Boolean equation. Only one signal source is required regardless of the number of equations in which the signal is used. After the signal becomes available, modifications which require the signal can be implemented by changes in the processor program for the specific equation. Opens and shorts on the signal path from multiplexer to source are also detected, thereby providing for isolation and resolution of problems. The processor can be programmed to include terms or parameters not normally included in electromechanical implementations such as power management inputs, flight profile inputs, self-test, and bit monitoring. Placing the solid state power controllers in proximity to loads provides load protection and switching at or near the loads.

Valuable cockpit room now utilized for circuit breakers, thus can be put to other uses; for example, the F-14 currently has 323 circuit breakers located in the pilot's and flight officer's cockpits. The crew control and display panel can be implemented as a dedicated display or can be shared with another display, depending upon the aircraft.

4.2.1 F-14 DATA BASE

Preliminary efforts to provide a data base for subsequent SOSTEL analysis and design involved the identification of the loads, transducers and control equations for the F-14 aircraft. This effort primarily involved analysis of the F-14 integrated weapon system functional diagrams (NAVAIR numbers 01-F14AAA-16 and 01-F14AAA-16A). These functional drawings provide a rapid insight into the aircraft subsystems. Where additional information was required schematic, layout, and wiring drawings were referenced. The resulting information provided is tabulated in Tables I, II and III of Appendix B. A description of the information and format of these tables is shown in the Tables 4-16, 4-17 and 4-18, respectively. A bibliography of the applicable F-14 data sources is tabulated in Table 4-19. A summary of the tabulated information is illustrated in Table 4-20.

The general approach in the analysis and tabulation involved tracing the circuit paths from the circuit breakers through the various power switching elements to the loads. Low-power signal paths sharing the main power paths were also included. Identification codes were assigned to each of the transducers and loads. The Boolean equations were developed utilizing these codes. Relays in the power switching paths were "eliminated" by identifying the relay controlling transducers. A number of iterations were required to ensure that all pertinent information was obtained. While the effort is not considered complete, it is detailed enough to allow a realistic assessment of the SOSTEL requirements of an F-14 aircraft. This was performed by prorating the tabulated results by the percentage of relay contacts covered during the tabulation and adding a growth factor as illustrated in Table 4-21. This information was utilized for arriving at a realistic evaluation of the processor requirements, the numbers and types of remote terminals, and their inputs and outputs.

TABLE 4-16. F-14 SOSTEL SIGNAL TRANSDUCERS

FIGURE ___ SHEET ___

1 Table Item #	2 Signal Name/Function	3 Identifier Code	4 Signal Source Box Identification	5 Point of Origin	6 Transducer Type	7 Preset Signal Characteristics	8 Associated Loads	9 Conventional Switches Being Replaced or Deleted	10 Operational Address	11 Reference Drawings	12 Associated Boolean Equation	13 Conditioning Technique

1. Table Item Number - Numbers each signal source in this table, these numbers correlate to the last three digits of the identifier code. Do to iterations during analysis the numbers associated with a particular figure may not be sequential.
2. Signal Name/Function - Identifies signal
3. Identifier Code - 6 digit alpha-numerics code as defined in SOW. These terms are the input terms of the Boolean equations.
4. Signal Source Box Identification - LRU or other identification number.
5. Point of Origin - Location in aircraft; fuselage station, water line, butt line, console, etc.
6. Transducer Type - Push, Toggle, Temperature, Limit; 4 PDT, TPDTCO, DPDT, etc.
7. Present Signal Characteristics - Switched 28v, open/ground, etc.
8. Associated Loads - Name of Loads that this signal controls or affects.
9. Conventional switches being Replaced or Deleted - Names and numbers of conventional switches being replaced or deleted where applicable.
10. Operational Address - 5 Digit alpha-numeric code as defined in SOW. These terms identify the multiplexer number and channel which will contain this signal.
11. Reference Drawings - Identifies the Integrated Weapon Systems Functional Diagrams (IWSFD); zone, or other identification from which the information was obtained.
12. Associated Boolean Equation - Identifies the Boolean equations which this signal is an input to. Refers to the Table Item Number of Table III.
13. Conditioning Technique - Identifies the technique (circuit type) by which this transducer will be made compatible with the SOSTEL multiplexer input signal requirements; i.e., Solid-State, Switched contacts, etc.

FIGURE - Relates to the NAVAIR 01-F14AAA-2-2-16 or 16A Integrated Weapon Systems Functional Diagrams (IWSFD) figure number.

TABLE 4-17. F-14 SOLID STATE POWER CONTROLLERS AND DRIVERS

FIGURE___ SHEET___

1 Table Item #	2 Type of Power Controller	3 Rating V & I	4 Associated Loads	5 Duty Cycle	6 Load Power Dissipation	7 P.C. Location	8 Conventional Devices Being Replaced	9 Operational Address	10 Identifier Code	11 Reference Drawings	12 Associated Boolean Equations

1. TABLE ITEM No. - Numbers each power controller in this table. These numbers correlate to the last three digits of the identifier code. Due to iterations during analysis the numbers associated with a particular figure may not be sequential.

2. Type of power controller - Identifies the type of power controller required; 1 pole, 2 pole, etc., AC, DC

3. Rating V & I - Voltage and Current Rating of Controller; 28 VDC, 115AC; actual or circuit breaker rating where applicable.

4. Associated Loads - Identifies the load(s) the controller will interface to.

5. Duty Cycle - Actual or predicted duty cycle (ON-OFF of controller) where applicable.

6. Load Power Dissipation - Power dissipation of the load (Maximum Steady State).

7. P.C. Location - Location in the aircraft, fuselage station, console, etc.

8. Conventional devices being replaced - Identify the circuit breakers, relays or other devices which this Solid State Controller will replace where applicable

9. Operational address - The Operational Address identifies the De-multiplexer number and channel number which will provide the control signal for this Solid State Controller. This is a 5 digit alpha-numeric code as specified in the SOW.

10. Identifier Code - The Identifier Code is a 6 digit alphanumeric code as specified in the SOW. It is the output term of the Boolean equation.

11. Reference Drawings - Identifies the functional drawings, etc., page number, zone etc. from which the information was obtained.

12. Associated Boolean Equation - Refer to the Table Item number of Table III for a means of cross referencing.

FIGURE - Relates to the NAVAIR 01-F14AAA-2-2-1C or 1CA Integrated Weapon Systems Functional Diagrams (IWSFD) figure number.

TABLE 4-18. F-14 SOSTEL BOOLEAN EQUATIONS

FIGURE ____ SHEET ____

1 Table Item #	2 Boolean Equation	3 Transducer List Cross Reference	4 Solid State Controller List Cross Reference	5 Bus/Load Management Priority	6 Special Considerations	7 Reference Drawings	8 Equation Description & Notes

1. Table Ident Number - Numbers each equation in this table; these numbers correlate to the last three digits of the Identifier Code. Due to iterations during analysis the numbers associated with a particular figure may not be sequential.

2. Boolean Equation - Boolean equation - Identifier codes of Table I are inputs, Identifier Codes of Table II are outputs.

3. Transducer List Cross Reference - Identifies the input transducers of the Boolean equation by *referencing* to the Table Identification numbers of Table I.

4. Solid State Controller List Cross Reference - Identifies the output of the Boolean equation by referencing to the Table Identification number of Table II.

5. Bus/Load Management Priority - Identifies the priority of this equation as related to the BUS/LOAD management profile.

6. Special Considerations - Identifies other parameters of the equation, i.e., time delays, sequential parameters, etc.

7. Reference Drawings - Identifies the functional drawing, etc., from which the equation was derived.

8. Equation Description & Notes - Describes the equation and identifies unusual characteristics.

FIGURE - Relates to the NAVAIR 01-F14AAA-2-2-16 or 16A Integrated Weapon Systems Functional Diagrams (IWSFD)

TABLE 4-19. BIBLIOGRAPHY OF F-14 DATA SOURCES

NAVAIR NO.	TITLE
01-F14AAA-1	NATOPS FLIGHT MANUAL
01-F14AAA-1A	SUPPLEMENTAL NATOPS FLIGHT MANUAL
01-F14AAA-2-1	GENERAL AIRCRAFT INFORMATION
01-F14AAA-2-2-1	LANDING SYSTEMS
01-F14AAA-2-2-2	ENVIRONMENTAL CONTROL SYSTEMS
01-F14AAA-2-2-3	ESCAPE SYSTEMS
01-F14AAA-2-2-4	FLIGHT CONTROL SYSTEMS
01-F14AAA-2-2-5	HYDRAULIC POWER SYSTEMS
01-F14AAA-2-2-6	PROPULSION SYSTEMS
01-F14AAA-2-2-7	FUEL AND IN-FLIGHT REFUELING SYSTEMS
01-F14AAA-2-2-8	INSTRUMENTS AND DISPLAYS
01-F14AAA-2-2-9	ELECTRICAL POWER, POWER DISTRIBUTION, AND LIGHTING SYSTEMS
01-F14AAA-2-2-10	NAVIGATION SYSTEMS
01-F14AAA-2-2-16	INTEGRATED WEAPON SYSTEMS FUNCTIONAL DIAGRAMS
01-F14AAA-2-2-16A	INTEGRATED WEAPON SYSTEMS FUNCTIONAL DIAGRAMS
A51DCVAH004	ELECTRICAL GENERATING SECTION OF THE INTEGRATED DRIVE GENERATOR SYSTEM
A51A60773V13C	LEFT GLOVE SWITCHING ASSY WIRING DIAGRAM
A51A60772V9C	RIGHT GLOVE SWITCHING ASSY WIRING DIAGRAM
A51A60781V2D	FORWARD SWITCHING ASSY WIRING DIAGRAM
A51A60793V2B	AFT COCKPIT SWITCHING ASSY WIRING DIAGRAM
A51A605448V4B	LANDING GEAR SAFETY - INTERLOCK SYSTEM WIRING DIAGRAM
GRUMMAN	
ADVANCED DEVELOPMENT REPORT ADR 09-03-76.1	THE DESIGN OF A SOLID STATE DATA BUS SYSTEM

TABLE 4-20. SUMMARY OF TABULATED INFORMATION

• NUMBER OF EQUATIONS TABULATED	=	544
• NUMBER OF CONTROLLERS TABULATED	=	386
• NUMBER OF SIGNAL DRIVERS TABULATED	=	158
• NUMBER OF TRANSDUCERS TABULATED	=	396
• NUMBER OF SEQUENTIAL EQUATIONS TABULATED	=	10
• NUMBER OF TIME DELAY EQUATIONS TABULATED	=	18
• % OF CIRCUIT BREAKERS ELIMINATED = 300/323	=	93%
• % OF RELAYS ELIMINATED = $\frac{125}{151}$	=	82%
• NUMBER OF EQUATIONS TABULATED NOT CONTAINING TRANSDUCER TERMS	=	149
• AVERAGE NUMBER OF TRANSDUCER INPUTS PER EQUATION	=	2.25
• NUMBER OF SOSTEL SOLID STATE TRANSDUCERS	=	186
• NUMBER OF RESISTOR DIVIDER TRANSDUCERS	=	116
• NUMBER OF GPMS TYPE TRANSDUCER SIGNALS	=	94
• AVERAGE NUMBER EQUATIONS ASSOCIATED WITH EACH TRANSDUCER	=	1

TABLE 4-21. ESTIMATE TOTAL TRANSDUCERS, PC, SIGNALS, EQUATIONS

Power Controllers and GPMS Signals (Lamps, Flags, etc)

1) 600 Tabulated (Total)

2) 415 Standard type Power Controllers
185 Signal type GPMS Signal

3) Prorate above based on 82% complete and 20% growth

$\frac{600}{(.82)} \times 1.2 = 878$ total (SSPC & Signal type)

4) Untabulated controllers are mostly signal type

415 Standard SSPC
185 Signal types
600 Tabulated

278 Signal types Untabulated

878 Total

Boolean Equations

1) 544 Tabulated

2) Prorate based on 82% complete and 20% growth

3) $\frac{544}{(.82)} \times 1.2 = 796 \sim 800$ (Total)

Transducers

1) 396 Tabulated

2) Prorate on 82% complete and 20% growth.

3) $\frac{396}{(.82)} \times 1.2 = 580$ (Total)

The number of circuit breakers which were accounted for during the analysis is tabulated on Table 4-22. Ninety-three percent of the 323 circuit breakers could be deleted. The remainder are mainly very large breakers which were not considered candidates for replacement by solid state power controllers. Tables 4-23 and 4-24 are tabulations of the relays in the left and right glove vane relay boxes which would be deleted in a complete SOSTEL system. Each relay contact was red lined as the tabulation of equations was being performed. The remaining unaccounted for contacts are primarily associated with discrete signal paths. Table 4-25 is a listing of the time delay and sequential equations encountered during the tabulation. These functions are further described on Table III of Appendix B. They are presently implemented by electronic or electromechanical monostable or bistable circuitry, and would require equivalent processor timer programs in the SOSTEL system. Table 4-26 is a summary of the major equipments which could be deleted on a SOSTEL F-14A aircraft. Table 4-27, a tabulation of the transducers, identifies the various types and the conditioning technique. The conditioning technique was assigned based upon our best engineering estimate of the difficulty of substituting a solid state transducer for the present electromechanical device. This judgement was primarily based upon whether the transducer was part of a larger unit or a relatively isolated device. Where transducer sources was part of a relay or switch contacts which could not be replaced by a solid state device, the resistor divider technique was selected. Use of an external signal adapter or preferably a GPMS terminal was allocated to those signals which could not be conditioned by either of the two previous techniques. Table 4-28 is a summation of the number of input transducers associated with the Boolean equations. There are an average of three transducers per equation. One hundred and forty-nine equations contain no transducer terms. These equations are the equivalent of those circuit paths which go directly to the loads from the buses through circuit breakers. The circuit breakers were considered protective elements only as they do not normally provide

TABLE 4-22. CIRCUIT BREAKERS PERCENT COMPLETED

Panel	No. of CB's	Completed
PILOTS LEFT KNEE PANEL	20	19
PILOTS RIGHT KNEE PANEL	12	12
NFO #1 PANEL	57	53
NFO #2 PANEL	31	30
NFO #3 PANEL	25	23
NFO #4 PANEL	30	26
NFO #5 PANEL	14	14
NFO #6 PANEL	30	29
NFO #7 PANEL	55	52
NFO #8 PANEL	49	42
	323	300

$$\frac{300}{323} = 93\%$$

TABLE 4-23. LEFT GLOVE RELAY BOX - PERCENT OF RELAYS ELIMINATED

RELAY No.	%	RELAY No.	%	RELAY No.	%
K1	1	K38	1	K70	1
K23	1	K10	1	K68	1
K45	1	K42	1	K51	1
K22	1/2	K53	1	K14	0
K17	3/4	K52	1	K39	1
K59	1	K26	1	K33	1
K21	1	K27	1	K34	1
K35	1	K30	3/4	K69	1
K6	1	K58	0	K77	1
K20	1	K16	1	K89	1
K4	1	K24	0	K57	1
K25	1	K15	1	K85	1
K2	3/4	K61	1	K84	1
K56	1/2	K79	0	K66	1/4
K18	1	K62	1	K86	1
K8	1	K63	1	K67	1/4
K9	1	K64	1	K87	1
K7	1	K82	1	K80	1
K51	3/4	K83	1	K61	1
K11	1	K50	1	K88	1
K26	1	K40	1	K90	1
K19	1	K46	1	K201	1
K12	1	K41	1	K200	1
K13	1	K49	1	K93	1
K39	1	K47	1	K91	1
K29	1	K45	1	K98	0
K54	1	K48	1	K99	0

81 Relays total

71½ Relays completed

1 = All contacts eliminated

0 = No contacts eliminated

$\frac{71.5}{81} = 88\%$

TABLE 4-24. RIGHT GLOVE RELAY BOX - PERCENT OF RELAYS ELIMINATED

RELAY No.	%	RELAY No.	%	RELAY No.	%
K8	1	K9	1	K96	0
K22	1	K33	1	K60	3/4
K21	1	K25	1	K41	1
K14	1	K2	1	K35	0
K38	1/2	K28	1	K73	1
K11	1	K19	1	K54	1
K59	1/2	K49	1	K71	0
K26	1/3	K12	3/4	K43	1
K13	1	K50	1	K70	0
K10	1	K30	1	K51	1
K56	1	K44	1	K52	1
K58	1	K1	3/4	K83	0
K24	1	K72	1	K34	0
K57	1	K32	1/2	K48	1
K40	1	K77	1	K47	1
K55	1	K78	1	K46	1
K6	1	K16	1	K45	1
K7	1	K4	1/2	K69	1
K200	1	K36	0	K68	1/2
K10	1/2	K31	1	K86	0
K29	1	K94	1/2	K87	0
K25	1	K3	1	K88	2/3
K20	2/3	K15	1	K202	0
				K201	0

70 Relays total

53.5 Relays eliminated

1 = All contacts eliminated

0 = No contacts eliminated

$\frac{53.5}{70} = 76\%$

TABLE 4-25. AAES TIME DELAY AND SEQUENTIAL EQUATIONS TABULATED

Equation Ident	IWSFD Figure No.	Equation Type
UCL310	1	Sequential
UCL311	1	Sequential
LAL107	3	Sequential
LAL108	3	Sequential
LAL109	3	Sequential
LAL207	3	Sequential
LAL208	3	Sequential
LAL209	3	Sequential
KCL140	16	Time Delay
KCL141	16	Time Delay
AML148	16	Time Delay
AML149	16	Time Delay
AML150	16	Time Delay
AML151	16	Time Delay
GHL287	30	Sequential
HQL214	32	Sequential
HJL172	33	Time Delay
QSL262	35	Time Delay
QSL263	35	Time Delay
KJL193	39	Time Delay
KJL194	39	Time Delay
LNL160	44	Time Delay (Flash)
LNL161	44	Time Delay (Flash)
LNL162	44	Time Delay (Flash)
LNL163	44	Time Delay (Flash)
LNL164	44	Time Delay (Flash)
LNL165	44	Time Delay (Flash)
LNL166	44	Time Delay (Flash)
Total = 28		

TABLE 4-26. COMPONENTS DELETED FROM AAES-F-14 PRODUCTION AIRCRAFT

1.	93% of the Circuit Breakers (300 of 323)
2.	Left Glove Relay Box (81 Relays)
3.	Right Glove Relay Box (70 Relays)
4.	AC Flasher (600S19)
5.	Aft Cockpit Relay Box (793A1)
6.	Forward Switching Assembly (781A1)
7.	Rain Repellent Timer (40M2)
8.	Hyd Backup Contactor Assembly (787A1)

TABLE 4-27. TRANSDUCER CATEGORIES

Figure	Solid State							Resistor Divider Adapter							External Signal Adapter							Total
	SL	ST	SPB	SS	SR	SPR	STP	RL	RT	RPB	RS	RR	RPR	RTP	RRL	EL	ET	EPB	ES	ER	EPR	ETP	ESG	
1	6	1	3	2	5	2		26															1	46
2	15				1	1		3							4									24
3	3	5	1		2																		3	14
4																								0
5	2				2			7	1														1	13
6																								0
7																1				1				2
8		1	1		2																			4
9															1								2	3
10																							7	7
11		1																						1
12		2																						2
13																								0
14		1																						1
15																							1	1
16		3	2																				2	7
17				3																				3
18			1						1	1														3
19								4	1	1														6
20												1											15	16
27																							1	1
29	4		1		1			2															1	9
30	7	4				2		9		1													2	25
32		6	4		1	2	3						1		1	4							2	24
33		5					1																1	7
34	1	2																						3
35		3				1	1		1				1	1									1	9
37		1											1	1	1									4
38							1																2	3
39	7							6															2	15
40		3						8								2								13
41																								0
42	1	10				2									5									18
43	2	5		10					3					1	1								8	30
44	2	7						1				1												11
45									9															9
46	9	4				2		1					2		3		2						12	35
1A								2															6	8
3A																							8	8
4A														1	1		1						4	7
5A		2																					1	3
Totals	59	66	13		5	24	12	6	69	16	3		2	5	4	17	6	4		1			83	
Total			185									116								94				

301 SOSTEL Compatible Signal

94 GPMS Type Signal

PREFIX: S = SOLID STATE, R = RISISTOR DIVIDER ADAPTER, E = EXTERNAL SIGNAL ADAPTER (GPMS)

L = LIMIT, T = TOGGLE, PB = PUSHBUTTON, S = SLIDE, R = ROTARY

PR = PRESSURE, TP = TEMPERATURE, SG = SIGNAL, RL = RELAY

TABLE 4-28. F-14 SOSTEL III EQUATIONS (SHEET 1 OF 2)

Figure No.	No. of Input Transducer Terms													No. of Equations
	0	1	2	3	4	5	6	7	8	9	10	11	12+	
1	16	9	16	6					2				2	51
2	9	1		2	3		1	2	1			1		20
3	2			3	1								6	12
4				2	2									4
5		2	1	1									2	6
6	6													6
7	4	1	1											6
8	11	3	1											15
9	1	1	1		1									4
10	2	2	5											9
11							1							1
12					1		1							2
13	1			1										2
14	9	1												10
15	6	2	1		2									11
16	21	4	2	4		1								32
17	5	6												11
18	3	2	1											6
19	2	10												12
20	2	34	6											42
27	1	1												2
29	1	6	3	2										12
30	1	5	5	1	2	2	1		2		1		2	22
32	4	11		4	3						1	1	2	26
33	1	3	2	1										7
34		2	3											5
35	4		1	2	3	2	1			2				15
37		1							1					2
38	10	1												11
39											2			2
40			2	2	3	2	1		2					12
41		2	1	1		1								5
42	5	7	3	2	3	3		1	1		1	1		27

TABLE 4-28. F-14 SOSTEL III EQUATIONS (SHEET 2 OF 2)

Figure No.	No. of Input Transducer Terms													No. of Equations
	0	1	2	3	4	5	6	7	8	9	10	11	12+	
43	4	9	4	4	5	5	1		1	1				34
44			3	1	2	2	2							10
45	2	8	2											12
46	2	5	5	7	3				3	1				26
1A	8	1	2	1	3	1								16
3A	3		2				1	3	1		1			11
4A		9	1	1	1	1			1					14
5A	3	8												11
	149	157	74	48	38	20	10	6	15	4	6	3	14	544/544

NOTE:

Figure No. relates to NAVAIR 01-F14 AAA-2-2-16 Integrated Weapons System Functional Drawing from which most of the equations were identified.

switching capability. Table 4-29 is a tabulation of the number of equations associated with each of the first 200 transducers tabulated. It was used to provide an insight into the processor requirements if a modified SOSTEL polling system were used.

TABLE 4-29. NUMBER OF EQUATIONS ASSOCIATED WITH EACH OF THE FIRST 200 TABULATED TRANSDUCERS

Eq Ident	No. of Eq	Eq Ident	No. of Eq	Eq Ident	No. of Eq	Eq Ident	No. of Eq
001	2	051	4	101	4	151	1
002	81	052	23	102	81	152	1
003	11	053	1	103	3	153	1
004	11	054	8	104	1	154	2
005	7	055	16	105	1	155	1
006	4	056	3	106	1	156	1
007	3	057	1	107	1	157	1
008	1	058	1	108	1	158	1
009	1	059	3	109	1	159	1
010	1	060	3	110	1	160	1
011	1	061	3	111	1	161	1
012	1	062	3	112	2	162	1
013	1	063	3	113	1	163	13
014	1	064	3	114	1	164	1
015	1	065	3	115	1	165	6
016	1	066	3	116	2	166	5
017	4	067	3	117	1	167	5
018	1	068	28	118	2	168	6
019	1	069	2	119	1	169	5
020	1	070	2	120	2	170	5
021	3	071	2	121	2	171	2
022	3	072	1	122	1	172	4
023	3	073	8	123	1	173	3
024	3	074	1	124	4	174	8
025	9	075	1	125	2	175	2
026	4	076	4	126	1	176	2
027	6	077	5	127	5	177	1
028	4	078	2	128	3	178	2
029	4	079	1	129	1	179	2
030	4	080	4	130	1	180	10
031	8	081	5	131	12	181	2
032	11	082	2	132	12	182	4
033	1	083	1	133	9	183	2
034	1	084	1	134	9	184	2
035	1	085	6	135	12	185	2
036	2	086	7	136	12	186	2
037	2	087	6	137	6	187	2
038	2	088	1	138	1	188	2
039	2	089	1	139	3	189	2
040	2	090	2	140	3	190	1
041	2	091	2	141	1	191	1
042	2	092	4	142	1	192	3
043	2	093	1	143	1	193	2
044	2	094	1	144	1	194	3
045	1	095	2	145	2	195	3
046	1	096	1	146	1	196	1
047	2	097	2	147	1	197	3
048	12	098	2	148	1	198	5
049	6	099	1	149	1	199	2
050	3	100	1	150	1	200	5

4.2.2 PGS/SOSTEL MONITORING AND LOAD MANAGEMENT

The SOSTEL-PGS interfaces for the AAES aircraft are examined relative to the present F-14 PGS configuration and requirements. The operation of the PGS is reviewed to develop the requirements of a SOSTEL system capable of performing load management. The PGS parameters required by SOSTEL are identified as well as minimum PGS display requirements. A technique to demonstrate load management in a flight demonstration aircraft is presented.

4.2.2.1 SOSTEL Control of PGS

The control of PGS via SOSTEL is not required. The generator control switches will interface directly to the generators in a manner similar to the present configuration. This is desirable since the generator detectors (undervoltage, overvoltage, etc) are configured in this unit to provide control of the main generator contactors directly. However, the state of these switches will be sampled by the SOSTEL system along with other PGS parameters to provide SOSTEL with display, summary, and management information.

4.2.2.2 SOSTEL Monitoring and Display of PGS

SOSTEL monitoring and display of PGS will be performed. The SOSTEL system can provide via the crew control and display a detailed read out of PGS configuration and failures. The SOSTEL master unit processor would store abnormal PGS conditions which occur during flight. This information would be used by flight and ground personnel as follows:

- Pre-flight ground check out of PGS
- Post flight analysis and troubleshooting of transient and permanent failures
- Alter PGS configuration.

In addition the SOSTEL system requires knowledge of the PGS system to provide automatic load shedding in the event of multiple main generator failures.

Figure 4-32 is a block diagram of F-14 PGS system utilized for the evaluation of the monitoring and display requirements. This configuration was used to review the PGS/SOSTEL requirements because it encompasses the requirements of the near-term flight test and a future production aircraft.

This system was used to provide the baseline for the PGS signals which the SOSTEL system must sample. The basic philosophy for display of PGS is oriented about displaying only those conditions upon which the pilot can take a positive action.

Using Fig. 4-32 as a baseline of the PGS, the parameters of Table 4-30 were tabulated. The Bendix CFG - DC link generator with split/parallel capability on both the 270-vdc and 400-cycle a-c outputs was used as a baseline machine. The remaining equipment were assumed to be similar or identical to the present F-14 equipments. Table 4-31 is a tabulation of the minimum PGS conditions which should be displayed on the crew control and display panel along with the PGS parameters which control the display as well as possible pilot options.

4.2.2.3 Load Priorities

The present F-14 load priority system utilizes the essential buses to ensure that the high priority loads are powered in the event of multiple failures of the main generators or transformer rectifiers. The operation of the system is as follows. The essential a-c and d-c buses are normally fed through the essential a-c and d-c contactors (AT1, AT2, DT1 and DT2 of Fig. 4-32) by the left main a-c and d-c buses, respectively. The emergency generator is connected to the other poles of these contactors. The operation of the hydraulic motor that drives the emergency generator is controlled by a solenoid-operated hydraulic shutoff valve. The valve automatically returns to the open position with the loss of the d-c electrical power that holds the solenoid-operated

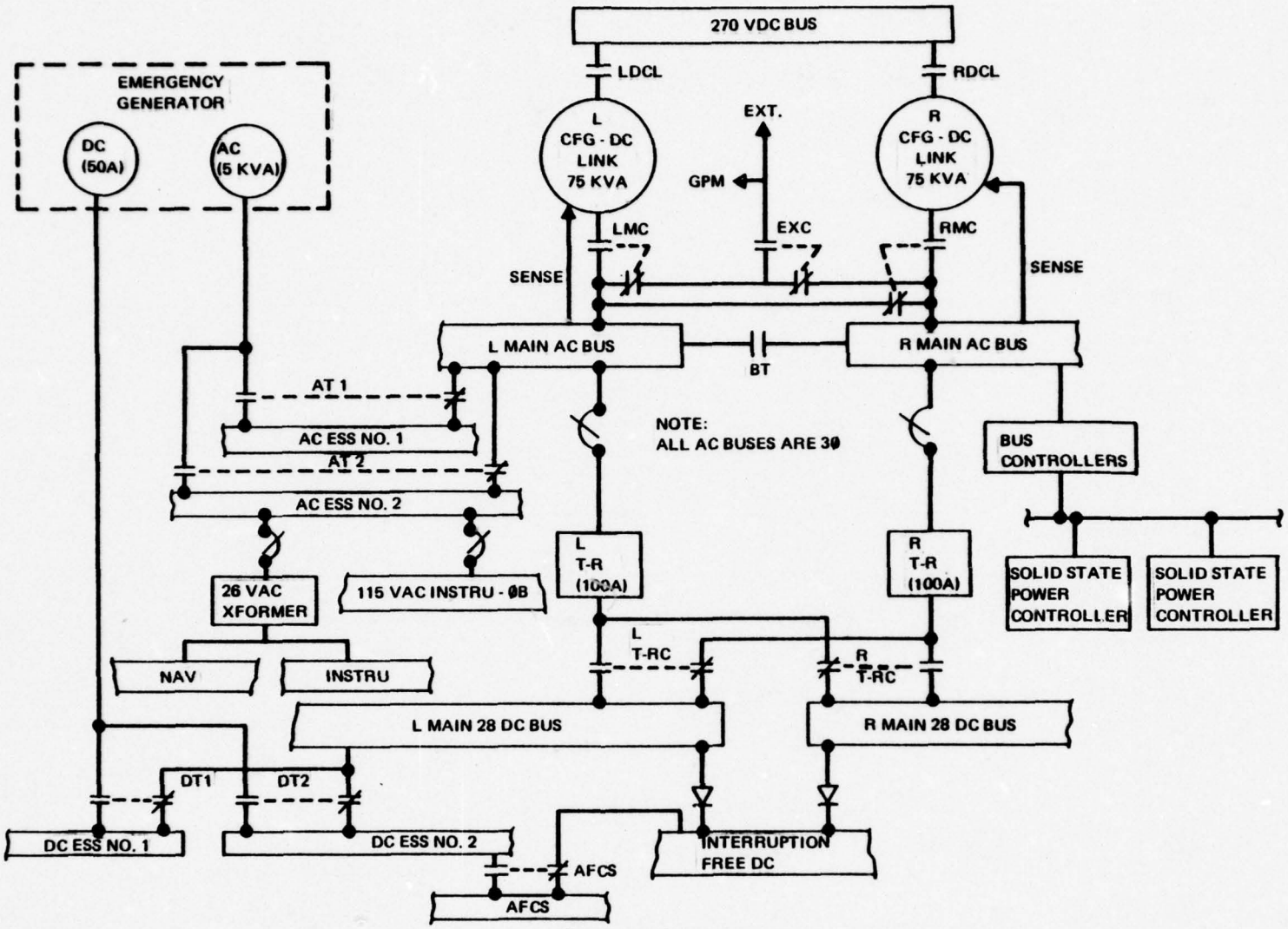


Figure 4-32. F-14A Power Distribution - Flight Test Configuration

TABLE 4-30. SOSTEL PGS MONITOR POINTS (SHEET 1 OF 3)

Signal Name	Signal Source
1. Left Generator - Normal	Left Generator Cockpit Switch
2. Left Generator - Off/Reset	Left Generator Cockpit Switch
3. Left Generator - Test	Left Generator Cockpit Switch
4. Right Generator - Normal	Right Generator Cockpit Switch
5. Right Generator - Off/Reset	Right Generator Cockpit Switch
6. Right Generator - Test	Right Generator Cockpit Switch
7. Emergency Generator - Normal	Emergency Generator Cockpit Switch
8. Emergency Generator - Off/Reset	Emergency Generator Cockpit Switch
9. Bus Tie - Parallel/Split	Bus Tie Cockpit Switch
10. Bus Tie - Auto	Bus Tie Cockpit Switch
11. External Power	External Contactor
12. Left AC Main Power	Left Main Ac Contactor
13. Right AC Main Power	Right Main AC Contactor
14. Bus Tie Position	Bus Tie Contactor
15. Left Generator Temperature	Left CFG-DC Link Temperatures
16. Right Generator Temperature	Right CFG-DC Link Temperatures
17. Left Generator Overvoltage	Left 270 VDC link Overvoltage Detector
18. Right Generator Overvoltage	Right 270 VDC Link Overvoltage Detector
19. Left Generator Undervoltage	Left 270 VDC Link Undervoltage Detector
20. Right Generator Undervoltage	Right 270 VDC Link Undervoltage Detector
21. Left Generator Underspeed	Left 270 VDC Link Protection Circuit
22. Right Generator Underspeed	Right 270 VDC Link Protection Circuit
23. Left Generator Shorted Diode	Left 270 VDC Link C.U.
24. Right Generator Shorted Diode	Right 270 VDC Link C.U.
25. Left Bus Fault Protection	Left 270 VDC Link Generator C.U.
26. Right Bus Fault Protection	Right 270 VDC Link Generator C.U.
27. Left Generator Circuit Breaker Control (270 VDC)	Left 270 VDC Link Generator C.U.
28. Right Generator Circuit Breaker Control (270 VDC)	Right 270 VDC Link Generator C.U.
29. Left Bus Tie Breaker Control	Left 270 VDC Link Generator C.U.
30. Right Bus Tie Breaker Control	Right 270 VDC Link Generator C.U.

TABLE 4-30. SOSTEL PGS MONITOR POINTS (SHEET 2 OF 3)

	Signal Name	Signal Source
31.	Left Difference Current Protection	Left 270 VDC Link Generator C.U.
32.	Right Difference Current Protection	Right 280 VDC Link Generator C.U.
33.	Left Generator Circuit Breaker Control (400 Cycle AC)	Left 400 Cycle AC Generator C.U.
34.	Right Generator Circuit Breaker Control (400 Cycle AC)	Right 400 Cycle AC Generator C.U.
35.	Left Bus Tie Breaker Control	Left 400 Cycle AC Generator C.U.
36.	Right Bus Tie Breaker Control	Right 400 Cycle AC Generator C.U.
37.	Left Overvoltage and Overexcitation Protection	Left 400 Cycle AC Generator Detector
38.	Right Overvoltage and Overexcitation Protection	Right 400 Cycle AC Generator Detector
39.	Left Undervoltage and Under-excitation Protection	Left 400 Cycle AC Generator Detector
40.	Right Undervoltage and Under-excitation Protection	Right 400 Cycle AC Generator Detector
41.	Left Under Frequency	Left 400 Cycle AC Generator Detector
42.	Right Under Frequency	Right 400 Cycle AC Generator Detector
43.	Left Over Frequency	Left 400 Cycle AC Generator Detector
44.	Right Over Frequency	Right 400 Cycle AC Generator Detector
45.	Left Difference Current Protection	Left 400 Cycle AC Generator Detector
46.	Right Difference Current Protection	Right 400 Cycle AC Generator Detector
47.	Left Real Current Sensing	Left 400 Cycle AC Generator Detector
48.	Right Real Current Sensing	Right 400 Cycle AC Generator Detector
49.	Left 28 VDC Bus Power	Left Transformer Rectifier Contactor
50.	Right 28 VDC Bus Power	Right Transformer Rectifier Contactor
51.	Essential #1 AC Bus Power	AT1 Contactor
52.	Essential #2 AC Bus Power	AT2 Contactor
53.	Essential #1 DC Bus Power	DT1 Contactor
54.	Essential #2 DC Bus Power	DT2 Contactor
55.	AFCS Bus Power	AFCS Contactor
56.	Bus Controller (n) Status	AC or DC Bus Controllers Control Line Status

TABLE 4-30. SOSTEL PGS MONITOR POINTS (SHEET 3 OF 3)

Signal Name	Signal Source
57. Emergency Generator Under Frequency	Emergency Generator Control Unit
58. Emergency Generator Under Voltage	Emergency Generator Control Unit
59. Left 270 VDC Bus Power	Left 270 VDC Contactor
60. Right 270 VDC Bus Power	Right 270 VDC Contactor
61. Motor Generator Solenoid Control	Motor Generator

TABLE 4-31. MINIMUM PGS DISPLAYS (SHEET 1 OF 2)

Display	Display Equation Parameters	Pilot Options
L DC Link Failure	1. L DC Link Contactor 2. L Gen. Cockpit Switch 3. L Engine Speed 4. Ext Power	L Generator Cockpit Switch to Off/Reset or Test
R DC Link Failure	1. R DC Link Contactor 2. R Gen Cockpit Switch 3. R Engine Speed 4. Ext Power	R Generator Cockpit Switch to Off/Reset or Test
L AC Failure	1. R AC Contact 2. R Gen Cockpit Switch 3. R Engine Speed 4. Ext Power	L Generator Cockpit Switch to Off/Reset or Test
R AC Failure	1. L AC Contactor 2. L Gen Cockpit Switch 3. L Engine Speed 4. Ext Power	R Generator Cockpit Switch to Off/Reset or Test

TABLE 4-31. MINIMUM PGS DISPLAYS (SHEET 2 OF 2)

Display	Display Equation Parameters	Pilot Options
L 28 VDC Failure	1. L AC Contactor 2. L Gen Cockpit Switch 3. L Engine Speed 4. Ext Power 5. L DC Contactor	None
R 28 VDC Failure	1. R AC Contactor 2. R Gen Cockpit Switch 3. R Engine Speed 4. Ext Power 5. R DC Contactor	None
Emergency Power On	1. L & R DC Link Contactors 2. L & R AC Contactors 3. L & R Engine Speed 4. Ext Power 5. L & R DC Contactors	None
AC Parallel AC Split	1. Bus Tie Contactor 2. Bus Tie Cockpit Switch 3. L & R AC Detectors	B.T. Cockpit Switch

valve closed. This action occurs automatically with the loss of both main a-c and/or d-c power sources, which involves a double power supply failure before the emergency generator is activated. In the event of such a failure, only the essential buses will be energized. Since the emergency generator is hydraulically driven, an approximate one second delay elapses from the time of automatic initiation before the generator delivers rated power to the essential a-c and d-c buses. In the event of a failure (i.e., both engines flame out) such that the hydraulic pressure is insufficient to operate the hydraulic motor at optimum output, the generator output drops below tolerances, and the emergency generator control disconnects the essential AC2 and DC2 (AT2 and DT2) contactors leaving only essential AC1 and DC1 buses energized.

Thus, the basic priority of the system is as follows (in order of highest priority):

- Essential AC1 and DC1 buses
- Essential AC2 and DC2 buses, and the following subbuses which are fed by them: a) NAV Bus, b) instrument buses, c) AFCS Bus
- Left and right main a-c and d-c buses.

Using the above criteria, the SOSTEL equations and solid-state power controllers were assigned priorities based upon the buses from which the present loads derive power. This association was tabulated in Table III, SOSTEL Boolean Equation of Appendix B, and are summarized in Table 4-32. Seventy-eight equations are of priority 1; 277 are priority 2; and 194 are priority 3. The associated identifier number relates the applicable equation and controller to its priority assignment. In addition, the PGS emergency mode in which the loads will be powered by the emergency generator is tabulated under the column titled - PGS MODE. These PGS modes are further described in the subsequent SOSTEL load management section.

4.2.2.4 SOSTEL Load Management

The basic SOSTEL load management concept involves a software application of the

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 1 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
001	2	2	036	3	-	071	3	-
002	2	2	037	2	2	072	3	-
003	2	2	038	2	2	073	3	-
004	2	2	039	2	2	074	3	-
005	2	2	040	2	2,3	075	2	2,3
006	2	2	041	1	1,2,3	076	2	2,3
007	2	2	042	1	1,2,3	077	-	-
008	2	2	043	1	1,2,3	078	2	2
009	2	2	044	1	1,2,3	079	2	2
010	3	-	045	1	1,2,3	080	1	1,2,3
011	2	2,3	046	2	2,3	081	1	1,2
012	2	2,3	047	2	2,3	082	-	-
013	2	2,3	048	2	2,3	083	-	-
014	2	2,3	049	2	2,3	084	-	-
015	2	2,3	050	2	2,3	085	3	-
016	2	2,3	051	1	1,2	086	2	2
017	2	2	052	1	1,2	087	2	2
018	3	-	053	1	1,2	088	2	2
019	2	2	054	2	2	089	2	2,3
020	2	2	055	2	2	090	2	2
021	2	2	056	3	-	091	2	2
022	2	2	057	3	-	092	2	2
023	2	2	058	1	1,2,3	093	2	2,3
024	2	2	059	2	2,3	094	2	2,3
025	2	2	060	1	1,2	095	2	2
026	2	2	061	3	-	096	2	2
027	3	-	062	3	1	097	2	2
028	3	-	063	2	2	098	2	2,3
029	2	2	064	2	2	099	1	1,2,3
030	2	2	065	2	2,3	100	1	1,2,3
031	3	-	066	2	2	101	2	2,3
032	2	2	067	2	2	102	2	2,3
033	2	2	068	2	2	103	2	2,3
034	3	-	069	3	-	104	2	2,3
035	3	-	070	3	-	105	2	2,3

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 2 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
106	2	2,3	141	2	2,3	176	3	-
107	2	2	142	1	1,2	177	3	-
108	2	2	143	1	1,2	178	3	-
109	2	2	144	1	1,2	179	3	-
110	2	2	145	1	1,2	180	2	2,3
111	3	-	146	1	1,2	181	3	-
112	2	2,3	147	1	1,2	182	2	2,3
113	2	2,3	148	1	1,2,3	183	2	2
114	2	2,3	149	1	1,2,3	184	2	2
115	2	2,3	150	1	1,2,3	185	2	2
116	2	2,3	151	1	1,2,3	186	2	2
117	3	-	152	1	1,2,3	187	2	2
118	3	-	153	1	1,2,3	188	2	2
119	2	2,3	154	1	1,2,3	189	2	2,3
120	2	2,3	155	1	1,2,3	190	2	2,3
121	2	2,3	156	1	1,2,3	191	2	2
122	2	2,3	157	1	1,2,3	192	2	2
123	2	2,3	158	2	2	193	2	2,3
124	2	2,3	159	3	-	194	2	2,3
125	2	2,3	160	3	-	195	2	2
126	1	1,2,3	161	3	-	196	2	2
127	1	1,2,3	162	3	-	197	2	2
128	1	1,2,3	163	3	-	198	2	2
129	1	1,2,3	164	3	-	199	2	2
130	1	1,2,3	165	3	-	200	2	2
131	1	1,2,3	166	3	-	201	2	2
132	1	1,2,3	167	3	-	202	2	2
133	1	1,2,3	168	3	-	203	2	2
134	1	1,2,3	169	3	-	204	3	-
135	1	1,2,3	170	3	-	205	3	-
136	1	1,2,3	171	2	2,3	206	3	-
137	3	-	172	2	2,3	207	2	2
138	3	-	173	3	-	208	2	2
139	3	-	174	3	-	209	2	2
140	2	2,3	175	3	-	210	2	2,3

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 3 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
211	2	2,3	246	2	2,3	281	2	2,3
212	2	2,3	247	2	2,3	282	2	2,3
213	2	2,3	248	2	2,3	283	2	2,3
214	2	2,3	249	2	2,3	284	2	2,3
215	2	2,3	250	2	2,3	285	2	2,3
216	2	2,3	251	2	2,3	286	2	2,3
217	-	-	252	2	2,3	287	2	2,3
218	2	2,3	253	2	2,3	288	2	-
219	2	2,3	254	2	2,3	298	2	2,3
220	2	2,3	255	2	2,3	290	2	-
221	2	2,3	256	2	2,3	291	2	-
222	3	-	257	2	2,3	292	2	-
223	3	-	258	2	2,3	293	2	-
224	2	2,3	259	3	-	294	2	-
225	2	2,3	260	3	-	295	2	2,3
226	2	2,3	261	3	-	296	2	-
227	2	-	262	2	2,3	297	2	2,3
228	2	-	263	2	2,3	298	2	2,3
229	2	2,3	264	2	2,3	299	2	-
230	2	2,3	265	2	2,3	300	2	2,3
231	2	-	266	2	2,3	301	2	2,3
232	2	2,3	267	1	1,2,3	302	2	2,3
233	2	2,3	268	1	1,2,3	303	2	2,3
234	2	2,3	269	3	-	304	2	2,3
235	2	2,3	270	1	1,2	305	2	2
236	2	2	271	2	2	306	2	2
237	2	2,3	272	2	2	307	2	2
238	2	2,3	273	1	1,2,3	308	2	2,3
239	2	2,3	274	2	2,3	309	2	2,3
240	2	2,3	275	1	1,2,3	310	2	2,3
241	2	2,3	276	1	1,2,3	311	2	2,3
242	2	2,3	277	2	2,3	312	2	2,3
243	2	2,3	278	2	2,3	313	2	2,3
244	2	2,3	279	2	2,3	314	2	2,3
245	2	2,3	280	2	2,3	315	2	2,3

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 4 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
316	2	2,3	351	3	-	386	3	-
317	2	2,3	352	3	-	387	3	-
318	2	2,3	353	3	-	388	3	-
319	2	2,3	354	3	-	389	3	-
320	2	2,3	355	3	-	390	3	-
321	2	2,3	356	3	-	391	3	-
322	3	-	357	3	-	392	3	-
323	3	-	358	3	-	393	3	-
324	3	-	359	3	-	394	3	-
325	1	1,2,3	360	3	-	395	3	-
326	1	1,2,3	361	3	-	396	3	-
327	1	1,2,3	362	3	-	397	3	-
328	1	1,2,3	363	3	-	398	1	1,2,3
329	1	1,2,3	364	3	-	399	1	1,2,3
330	1	1,2,3	365	3	-	400	1	1,2,3
331	3	-	366	3	-	401	1	1,2,3
332	3	-	367	3	-	402	2	2,3
333	1	1,2,3	368	3	-	403	2	2
334	3	-	369	3	-			
335	3	-	370	3	-			
336	1	1,2,3	371	3	-			
337	1	1,2,3	372	3	-			
338	3	-	373	3	-			
339	3	-	374	3	-			
340	3	-	375	2	2,3			
341	1	1,2	376	3	-			
342	3	-	377	2	2,3			
343	3	-	378	2	2			
344	3	-	379	1	1,2,3			
345	3	-	380	1	1,2,3			
346	3	-	381	1	1,2,3			
347	3	-	382	3	-			
348	3	-	383	3	-			
349	3	-	384	3	-			
350	3	-	385	3	-			

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 5 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
500	1	1,2,3	536	2	2,3	572	2	2
501	1	1,2,3	537	1	1,2,3	573	2	2,3
502	1	1,2,3	538	1	1,2,3	574	2	2,3
503	1	1,2,3	539	1	1,2,3	575	2	2,3
504	3	-	540	1	1,2,3	576	2	2,3
505	3	-	541	2	-	577	2	2,3
506	3	-	542	2	2,3	578	3	-
507	3	-	543	2	-	579	3	-
508	1	1,2	544	2	2,3	580	2	2
509	2	2	545	2	2,3	581	2	2
510	3	-	546	2	2,3	582	3	-
511	3	-	547	2	2,3	583	3	-
512	3	-	548	2	2,3	584	3	-
513	3	-	549	2	2,3	585	3	-
514	1	1,2	550	2	2,3	586	3	-
515	3	-	551	2	-	587	3	-
516	2	2	552	2	2,3	588	3	-
517	2	2	553	2	2,3	589	3	-
518	2	2	554	2	2,3	590	3	-
519	2	2,3	555	2	2,3	591	2	2,3
520	2	2	556	2	2,3	592	3	-
521	2	-	557	3	-			
522	2	-	558	2	2,3			
523	2	-	559	3	-			
524	2	-	560	2	2,3			
525	2	-	561	2	2			
526	2	-	562	3	-			
527	2	-	563	2	2			
528	2	-	564	3	-			
529	2	2,3	565	3	-			
530	3	-	566	3	-			
531	3	-	567	2	2			
532	-	-	568	3	-			
533	1	1,2	569	2	2			
534	1	1,2	570	2	2			
535	2	2,3	571	2	2			

TABLE 4-32. SOSTEL F-14 LOAD PRIORITIES AND ASSOCIATED PGS MODES (SHEET 6 OF 6)

Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode	Ident Code	Load Priority	PGS Mode
700	3	-	736	3	-			
701	3	-	737	-	-			
702	3	-	738	-	-			
703	1	1,2,3	739	-	-			
704	1	1,2,3	740	3	-			
705	1	1,2,3	741	3	-			
706	2	2	742	3	-			
707	3	-	743	3	-			
708	3	-	744	3	-			
709	3	-	745	3	-			
710	3	-	746	3	-			
711	3	-	747	-	-			
712	3	-	748	-	-			
713	3	-	749	-	-			
714	3	-	750	-	-			
715	3	-	751	-	-			
716	3	-						
717	3	-						
718	3	-						
719	3	-						
720	3	-						
721	3	-						
722	3	-						
723	3	-						
724	3	-						
725	3	-						
726	3	-						
727	3	-						
728	3	-						
729	3	-						
730	3	-						
731	3	-						
732	3	-						
733	3	-						
734	3	-						
735	3	-						

present hardware implementation of the essential buses. This concept involves the selective turn on of loads at the solid state power controller level as a function of their priority. This concept is necessary when a SOSTEL system is implemented in the prototype PGS configuration since there are no essential buses, and the emergency generator feeds the main a-c and d-c buses directly. Since the emergency generator can not support the entire F-14 load, only the priority 1, or 1 and 2 loads would be enabled when the emergency generator comes on line. This technique is, however, still applicable if the present F-14 bus configuration is maintained as will be described in the subsequent flight demonstration section. In addition the present configuration provides a flight proven PGS concept for flight safety when a limited SOSTEL system is demonstrated.

The load management concept involves recognizing four F-14 PGS system modes and associating them with the 3 load priorities

(1) Essential 1 a-c/d-c

(2) Essential 1/2 - a-c/d-c

(3) Essential 1/2 - d-c

(4) Normal

In the normal mode their is no need to shed loads, the PGS system has adequate power to support all loads. In the essential modes the emergency generator is suppling power. Since this generator can not support the entire load, only those loads on the essential buses will be enabled. Essential 1 a-c/d-c mode is a submode of essential 1/2 - a-c/d-c and is entered if the power availability of the emergency generator cannot supply all essential loads. Similarly essential 1/2 d-c is a submode entered if both transformer rectifiers fail.

The SOSTEL processor must be able to force those output terms in the ORAM which are not associated with essential loads to zero. This is required to ensure that nonessential loads will be turned off in the essential mode. In addition, the SOSTEL

demultiplexer design must be such that it comes up upon power application with all its output current drivers off. This is required to ensure that all loads are off when power comes on. A typical sequence of operation in the emergency mode would be as follows: Having lost both main a-c and/or d-c supplies, the aircraft will have no electrical power for one second or until the emergency generator is up to speed and comes on line. When this occurs, the SOSTEL system powered by essential 1 a-c bus will be energized. As mentioned previously, all loads will still be off since the SOSTEL demultiplexers come on line with their output current drivers off. The SOSTEL processor will sample via the multiplexers the various PGS parameters. The state of the PGS parameters previously identified in Table 4-30 are adequate to define that the emergency generator is supplying power and the various emergency configurations. Using this information the processor will place inhibits or force to zero all demultiplexer control bits which are not essential. The essential loads may be ON or OFF as a function of the normal Boolean solutions. Essential mode 1 a-c/d-c will be entered in a similar manner if the emergency generator cannot supply enough power to support all essential loads. This condition occurs when the contactors AT2 and DT2 open, indicating the essential 2 buses are de-energized. Similarly, loss of both transformer rectifiers while main a-c power is available would cause only the essential 28 vdc loads to be energized. The SOSTEL processor flow diagram for the above operation is illustrated in Fig. 4-33. The PGS parameters and equations for each decision box is tabulated below.

(1) Emergency generator ON = Emergency generator control solenoid de-energized.

(2) Essential 1/2 - a-c/d-c mode = essential contactors AT1, AT2, DT1 and DT2 closed

(3) Essential 1 - a-c/d-c mode - essential contactors AT1 and DT1 closed

(4) Essential 1/2 - d-c mode - essential contactors DT1 and DT2 closed.

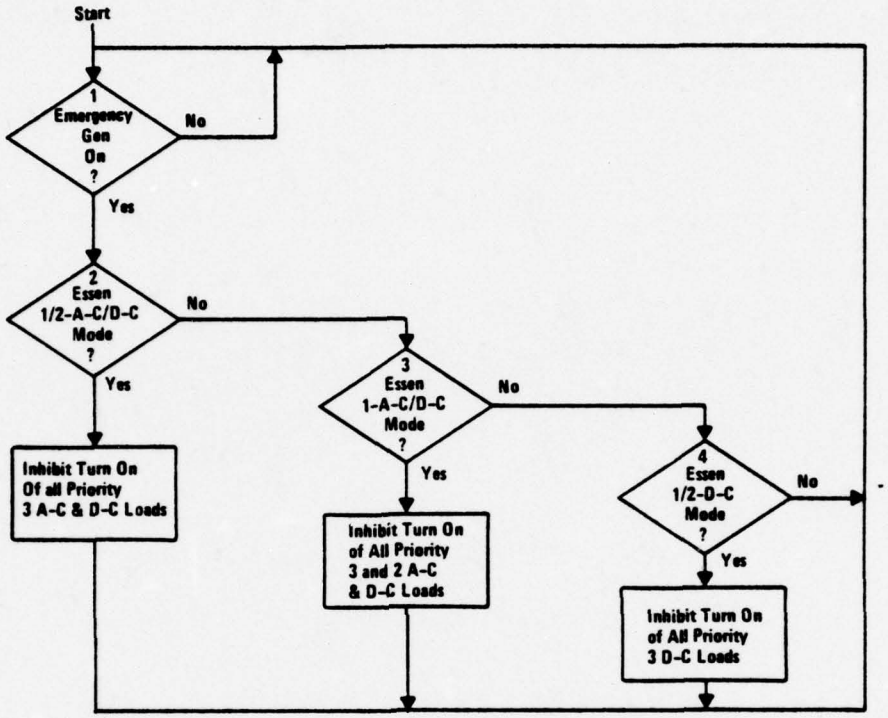


Figure 4-33. SOSTEL Processor Load Management Flow Diagram

4.2.2.5 Flight Demonstration of Load Management

To demonstrate the previously discussed load management concept in a flight demonstration aircraft and still maintain the flight proven integrity of the present PGS configuration the following is proposed: The loads which will be shed will be selected from the lowest priority buses; left and right main a-c/d-c buses. These nonessential loads are identified as priority 3 loads of Table 4-32. A complete description of these loads, their controllers, and equations can be found in Table II and III of Appendix B. A limited representative list is tabulated in the following Table 4-33. A representative number of these loads will be assigned to one demultiplexer. The emergency generator can be activated during flight by the master test emergency generator switch. When this switch is activated while the main buses are energized by the main generators, the emergency generator will be enabled, but will not supply power (contactors AT1, AT2, DT1, and DT2 remain in the main bus positions). Activating this switch will cause DEMUX to lose power for one second and alerts the MU to initiate its emergency mode load shedding program. This would allow the simulation of one of the load management programs previously discussed. By the addition of switches on the crew control and display panel all four load PGS configurations can be simulated with no impact on the integrity of the PGS configuration.

TABLE 4-33. TYPICAL NONESSENTIAL LOADS FOR FLIGHT TEST LOAD MANAGEMENT (SHEET 1 OF 4)

Ident Code	PGS Bus	Load Description
027	R.M. ϕC (CB3)	(1) Right AICS Total Temperature Probe Heater (32A9) P/O Air Inlet Control System
		(2) Right Aics Angle of Attack Probe Heater (81A4)
028	R.M. ϕB (CB6)	Left AICS Angle of Attack Probe Heater (81A3)
056	L.M. ϕC (CB8)	(1) Interrogator Switch Amplifier (10A3) (SA1568A/APX-76V)
		(2) Interrogator Receiver Transmitter (10A1) (RT868A/APX-76V)
057	L.M. DC (CB20)	(1) Interrogator Switch Amplifier (10A3) (SA 1568A/APX-76V)
		(2) AAI Control Panel (10A4) (C-7383/APX-76V)
		(3) Interrogator Synchronizer (10A2) (SN-416A/APX-76V)
		(4) Interrogator Receiver Transmitter (10A1) (RT 868A/APX-76V)
061	L.M. DC (CB6)	(1) Transponder Test Set (09A3) (TS-1843A/APX)
		(2) ADC Switching Unit (20A40)
		(3) IFF Control Panel (09A1) (C-6280 P/APX)
062	L.M. ϕA,B,C (CB55,52,49)	(1) Processor (84A1) (C8573/ASA-79) P/O Instruments & Displays
		(2) HSD Indicator (84A2)
		(3) ECM Display Indicator (84A3)
069	L.M. ϕA (CB12)	IMU Power Supply (06A2) (PP-6188/ASN-92V)
070	L.M. ϕB (CB10)	IMU Power Supply (06A2) (PP-6188/ASN-92V)
071	L.M. ϕC (CB9)	IMU Power Supply (06A2) (PP-6188/ASN-92V)
072	L.M. ϕA (CB5)	IMU (06A1) (CN-1263/ASN-92V)
073	L.M. ϕB (CB6)	IMU (06A1) (CN-1263/ASN-92V)

TABLE 4-33. TYPICAL NONESSENTIAL LOADS FOR FLIGHT TEST LOAD MANAGEMENT (SHEET 2 OF 4)

Ident Code	PGS Bus	Load Description
074	L.M. ϕC (CB2)	IMU (o6A1) (CN-1263/ASN 92V)
085	L.M. ϕA (CB6)	PMS Relay Assembly (27A38)
018	L.M. ϕA (CB27)	Wing Flap Glove Vane Controller Test 28VDC
137	L.M. DC (CB53)	Power Switching Unit (85A2) - Mid-Compression Bypass Power (SA-1749 AWG15)
138	L.M. DC (CB8)	Power Switching Unit (85A2) - Mech Fusing Sta 3 & 4 (SA-1749 AWG15)
139	L.M. DC (CB7)	Power Switching Unit (85A2) - Mech Fusing Sta. 5 & 6 (SA-1749 AWG15)
159	R.M. ϕA (CB18)	Taxi/Landing Light (60DS5)
160	R.M. ϕA (CB10)	Anti-Collision Light (60DS1), (60DS17), 50DS18)
161	R.M. ϕB,A (CB7)(CB10)	Tail Position Light - Bright (60DS16) (60DS27)
162	R.M. ϕB,A	Tail Position Light - Dim (60DS16) (60DS27)
163	R.M. ϕB,A (CB7)(CB10)	Wing Position Light - Bright (60DS8) (60DS10)
164	R.M. ϕB,A (CB7)(CB10)	Wing Position Light - Dim (60DS8) (60DS10)

TABLE 4-33. TYPICAL NONESSENTIAL LOADS FOR FLIGHT TEST LOAD MANAGEMENT (SHEET 3 OF 4)

Ident Code	PGS Bus	Load Description
165	R.M. ϕB, A (CB7) (CB10)	Left/Right - Upper/Lower Supplemental Position Lights - DIM (60DS6) (60DS7) (60DS9) (60DS11)
166	R.M. ϕB, A (CB7) (CB10)	Left/Right - Upper/Lower Supplemental Position Lights - Bright (60DS6) (60DS7) (60DS9) (60DS11)
167	R.M. ϕA (CB18)	Multichannel Lighting Control (56A1) (C9128/A)
168	R.M. ϕA (CB1)	Windshield Power Control (40A1) (C8612A)
169	R.M. DC (CB40)	High Defog Solenoid (40L4)
170	R.M. DC (CB40)	Medium Defog Solenoid (40L3)
174	R.M. DC (CB40)	Windshield Power Control (40A1) (C8621A)
175	R.M. ϕA,B,C (CB26, 23, 20)	WCS Coolent Pump (61B2)
176	R.M. ϕC (CB11)	WCS/Missile Controller (61A2) (AN/AWG-9)
177	R.M. ϕA,B,C (CB40,38,35)	Missile Coolent Pump Assembly (61B1) (AN/AWG-9)
178	R.M. DC (CB42)	ECS/Missile Controller (61A2) (AN/AWG-9)
179	R.M. DC (CB42)	WCS/Missile Controller (61A2) (AN/AWG-9)
204	L.M. DC (CB10)	Cooling Effect Controller (44A1)

TABLE 4-33. TYPICAL NONESSENTIAL LOADS FOR FLIGHT TEST LOAD MANAGEMENT (SHEET 4 OF 4)

Ident. Code	PGS Bus	Load Description
205	L.M. DC (CB10)	Equipment Hot Air Modulation Valve (44A5) Solenoid
206	L.M. DC (CB14)	Low Flow Solenoid Valve (27A45)
322	L.M. ϕA (CB53)	Power Supply (30A1) (AN/AWW-4V)
323	L.M. ϕB (CB44)	Power Supply (30A1) (AN/AWW-4V)
324	L.M. ϕC (CB50)	Power Supply (30A1) (AN/AWW-4V)
332	R.M. ϕB (CB16)	Gun Controller (31A1) (C8571A)
338	R.M. DC (CB24)	Power Switching Unit (85A2) - STA1 AIM-9 Cool Pwr (SA1745/AWG15)
339	R.M. DC (CB21)	Power Switching Unit (85A2) - STA8 AIM-9 Cool Pwr (SA1745/AWG15)

4.2.3 SOSTEL MASTER UNIT (MU) PROCESSOR ANALYSIS

Analysis of a baseline SOSTEL configuration for F-14 aircraft application is included for purposes of defining processor requirements. The SOSTEL configuration is basically the NADC-specified system with minor modification. The most significant change recommended is the inclusion of an alphanumeric display to promote improved coordination of man-machine operations, and the use of GPMS data terminals to perform SOSTEL type functions.

The processor analysis is sufficiently detailed to provide the assurance that the resulting estimates are realistic. Results indicate that memory requirements are reasonable. Processor computational load is less than 50% while bus operating time for I/O operations requires only one-third the capacity of a single one-MBPS data bus.

Considering the moderate nature of the processor and bus requirements, time shared bus operations are possible. Alternate, time shared bus configurations are examined as a separate task in the study.

Processor requirements necessary to meet F-14A SOSTEL prototype configuration have been determined for the baseline SOSTEL system. Since this analysis was initiated prior to a complete definition of the prototype system it was based on what was then considered a reasonable number of remote terminals of 10 MUX, 14 DEMUX and 2 MUX/DEMUX terminals (26 total). Subsequent development of the system indicates that the 7 MUX and 2 DT's performing signal sampling functions, and 11 DEMUX and 4 DT's performing signal driver functions, and 2 MUX/DEMUX terminals (26 total) are required. The final configuration is considered close enough such that the conclusions and analysis are valid and realistic. Results of this analysis are summarized as follows:

- Random Access Memory (16 Bit Words)

IRAM	50
BIRAM	50
TRAM	70
FRAM	70
ORAM	70
Miscellaneous RAM	514
20% Design Growth	304
25% Memory Margin	380
Total	1518 Words

- Fixed Program Memory (16 Bit Words)

Executive	150
Boolean Equation Processing	1355
Alphanumeric Lookup Table	8787
Miscellaneous Memory	656
20% Design Growth	3985
25% Memory Margin	4981
Total	19914 Words

- Processor and I/O Time

Average Processor Load	49.07%
Worst Case Processor Load	88.65%
Average Data Bus Load	31.88%
Worst Case Data Bus Load	84.40%

The approach used to establish processor requirements for the F-14 SOSTEL configuration is described in the paragraphs that follow.

SOSTEL subroutines are identified as shown in Table 4-34. Each subroutine has been analyzed (backup data included in analysis) to determine RAM, fixed memory, execution time and I/O time. This information is summarized in Table 4-34 by subroutine. Table 4-34 provides the basis for sizing RAM and program memory.

Figure 4-34 defines a flow chart of the SOSTEL program which mechanized the F-14 requirements. This figure was used as the basis of determining program execution time and I/O time per frame.

Time estimates are based on one complete pass through the F-14 prototype SOSTEL processor flow chart. This is a worst case condition in the sense that the maximum path through the program is analyzed.

For each routine and subroutine in the processor flow, we assigned the execution time per frame and the I/O time per frame for Table 4-34. Those routines whose update rate is less than 100/sec (10-millisec frame) are treated two ways to give a worst case, and an average processor and I/O time.

For example, those subroutines which are exercised every frame, the execution time per frame is included as both the maximum and average time columns. Routines used less frequently have their "execution time per frame" included in the max time column. The figure shown in the average time column represents the real time (usec/sec) entry for that routine multiplied by 10 milliseconds. This provides an average "execution time per frame." Similarly an average I/O time per frame is formed for subroutines whose update rate is less than the frame rate of 100/sec. Table 4-35 lists the inputs to the worst case and average processor and I/O time determination.

Figures 4-35 and 4-36 represents memory maps of the RAM and fixed program memories.

TABLE 4-34 SOSTEL PROCESSOR SI

Subroutine/Function	RAM No of Words	Fixed Program Words	Execution Time Per Frame, usec	Update Rate	Real Time usec/sec
Executive	-	150	100.98	10 msec	10,098
Initialization	-	11	2439	1 per flt	negligable
Data Bus Service (Rec & Trans)	-	41	14	AS REQD	-
Request Input or Fault Data From MUX	-	26	341.36	10 msec	34,136
Store Input Fault & Status Words	100	-	-	-	-
Receive Fault or Trip Data From DEMUX	-	7	12.92	1DEMUX/Sec	12.92
Store Fault, Trip & Status Words	140	-	-	-	-
Output Data to DEMUX & MUX/DEMUX	-	26	545.36	10 msec	54,536
Boolean Equation Processing	-	1355	2198.44	10 msec	219,844
Store Boolean Solutions in File	70	-	83.30	10 msec	8,330
Request PGS Monitor Data	-	12	340.00	10 msec	34,000
Store PGS Monitor Data	25	-	-	-	-
Fault/Trip Address Registers	64	-	-	-	-
Load Management Priorities	-	64	-	-	-
Load Shed Logic	-	54	589.56	10 msec	58,956
Request Control Panel Sw Data	-	25	35.36	10 msec	3,536
Store Control Panel Sw Data	3	-	-	-	-
Control Panel Sw Logic	-	58	37.74	10 msec	3,774
Alphanumeric Lookup Table	-	8787	40.29	5 sec	8.05
Output A/N Data to Displays	54	47	340.68	5 sec	68.13
Update Summary Data File	164	20	1565.36	1 sec	1565.36
Update Inhibit File	60	20	13.26	10 sec	1.33
Data/link Status Determination	-	10	61.27	infrequent	negligable
Processor Followup Mode	-	10	-	On CMD	-
Self-Test	-	128	50,615	As avail.	-
System Test	-	24	1504.84	Once on GND	-
System Status and Faults	1	4	2.38	10 msec	238
Transmit Data File	33	-	-	-	-
Receive Data File	33	-	-	-	-
Scratch Pad	100	-	-	-	-
Inhibit Faulted Inputs	1	14	117.3	10 msec	29,240
Check Inhibit File	-	12	407.36	10 msec	40,736
Output Discrete Data To Display	6	43	62.2	5 sec	12.44
20% Design Growth	304	3985	-	-	-
25% Memory Margin	380	4981	-	-	-
TOTAL	1518	19914			

2

LE 4-34 SOSTEL PROCESSOR SIZING

ion r sec	Update Rate	Real Time usec/sec	I/O Time per frame usec	I/O Time usec/sec	Comments
8	10 msec	10,098	-	-	I/O Time included in each subroutine
	1 per flt	negligable	-	-	occurs at Power-Up only
	AS REQD	-	-	-	Real time & I/O Time included in subroutine
36	10 msec	34,136	1200	120,000	Process Time and I/O Time overlap
	-	-	-	-	
92	1DEMUX/Sec	12.92	100	10,000	1 DEMUX Reports Trip/Fault per second
	-	-	-	-	
36	10 msec	54,536	1920	192,000	Process Time And I/O Time Overlap
44	10 msec	219,844	-	-	10 msec update is conservative
30	10 msec	8,330	-	-	
00	10 msec	34,000	120	12,000	
	-	-	-	-	
	-	-	-	-	Bus Mgmt is manual, Load Mgmt is automatic
	-	-	-	-	
56	10 msec	58,956	-	-	I/O Time included in "Output data to DEMUX"
36	10 msec	3,536	100	10,000	Process Time & I/O Time overlap
	-	-	-	-	
74	10 msec	3,774	-	-	
29	5 sec	8.05	-	-	Execution Time is per display Request
68	5 sec	68.13	680	136	Time is based on Alphanumeric Display
36	1 sec	1565.36	-	-	1 Update per second
26	10 sec	1.33	-	-	1 Inhibit CMD every 10 seconds
27	infrequent	negligable	140	negligible	Used only if Data Bus or Terminal fails
	On CMD	-	-	-	Only used on PRI/SEC Processor CMD
15	As avail.	-	-	-	Self-Test consumes all Spare Process Time
84	Once on GND	-	3766.72	-	System Test Done Only Prior To Flt
38	10 msec	238	60	6000	
	-	-	-	-	
	-	-	-	-	
	-	-	-	-	
3	10 msec	29,240	-	-	Execution time Assumes a Fault on all MUX
36	10 msec	40,736	-	-	
2	5 sec	12.44	160	32	
	-	-	-	-	Growth Margin During Design Phase
	-	-	-	-	Spec Memory Margin

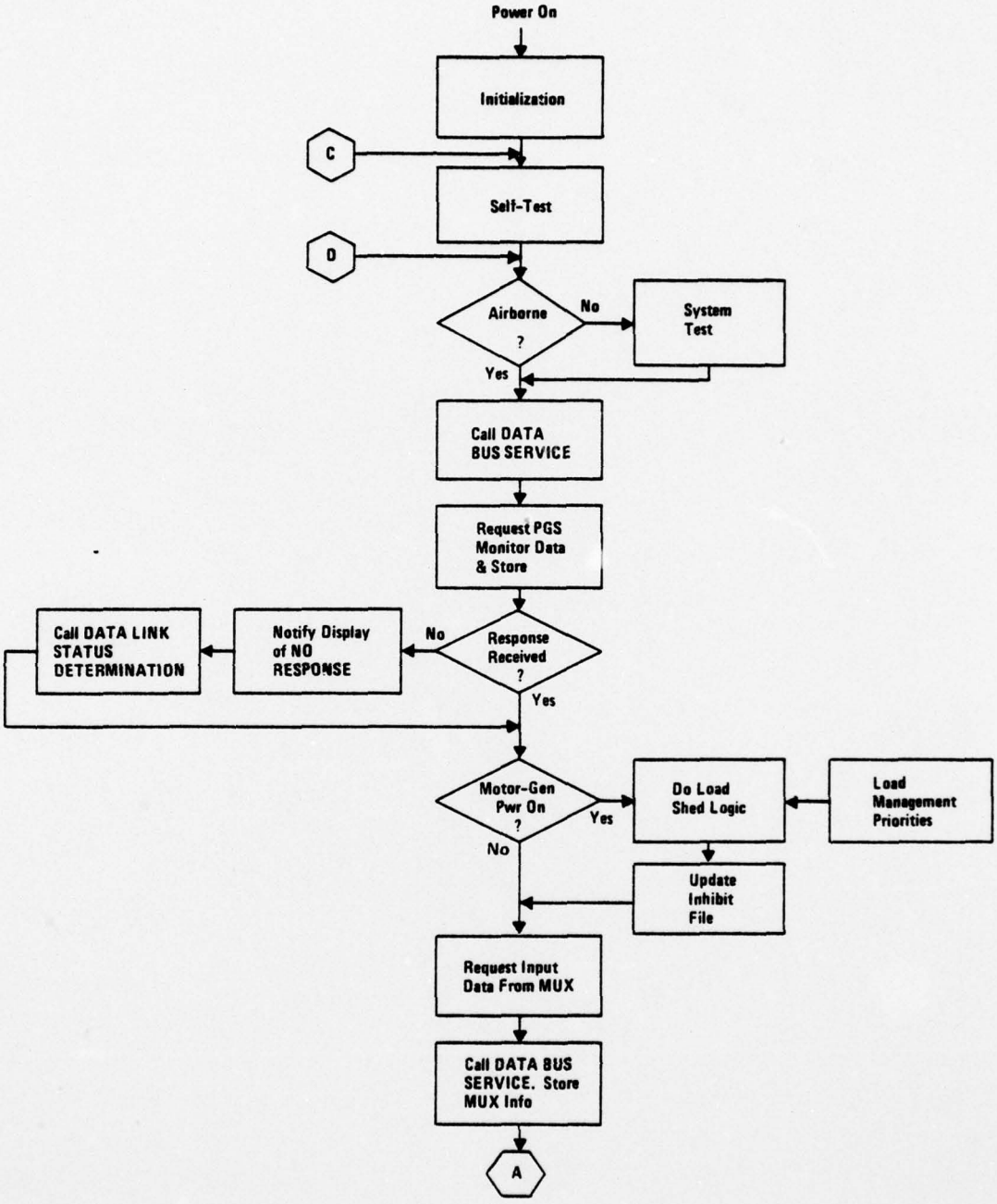


Figure 4-34. F-14 Sostel Processor Flow Diagram (Sheet 1 of 3)

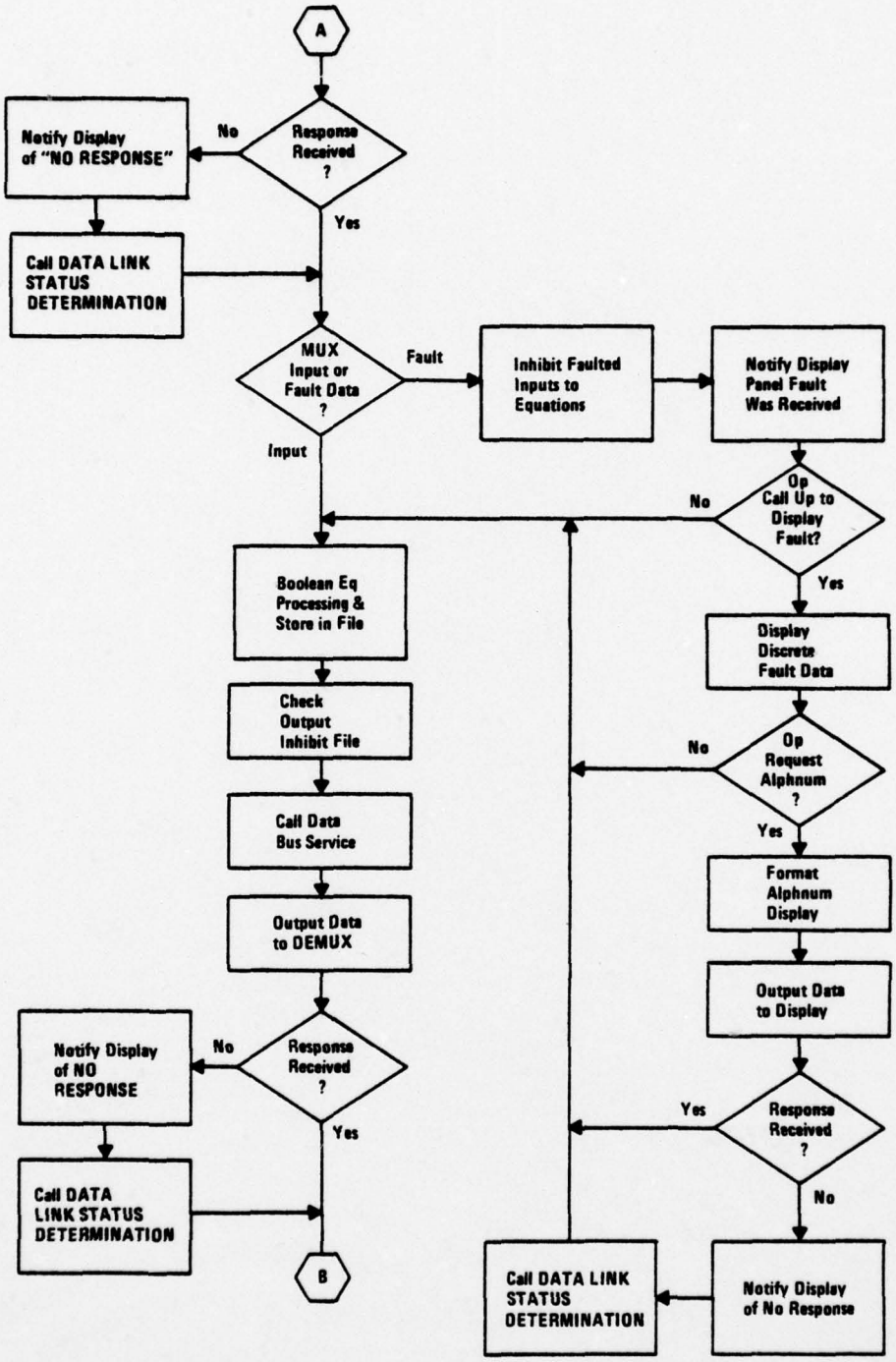


Figure 4-34. F-14 Sostel Processor Flow Diagram (Sheet 2 of 3)

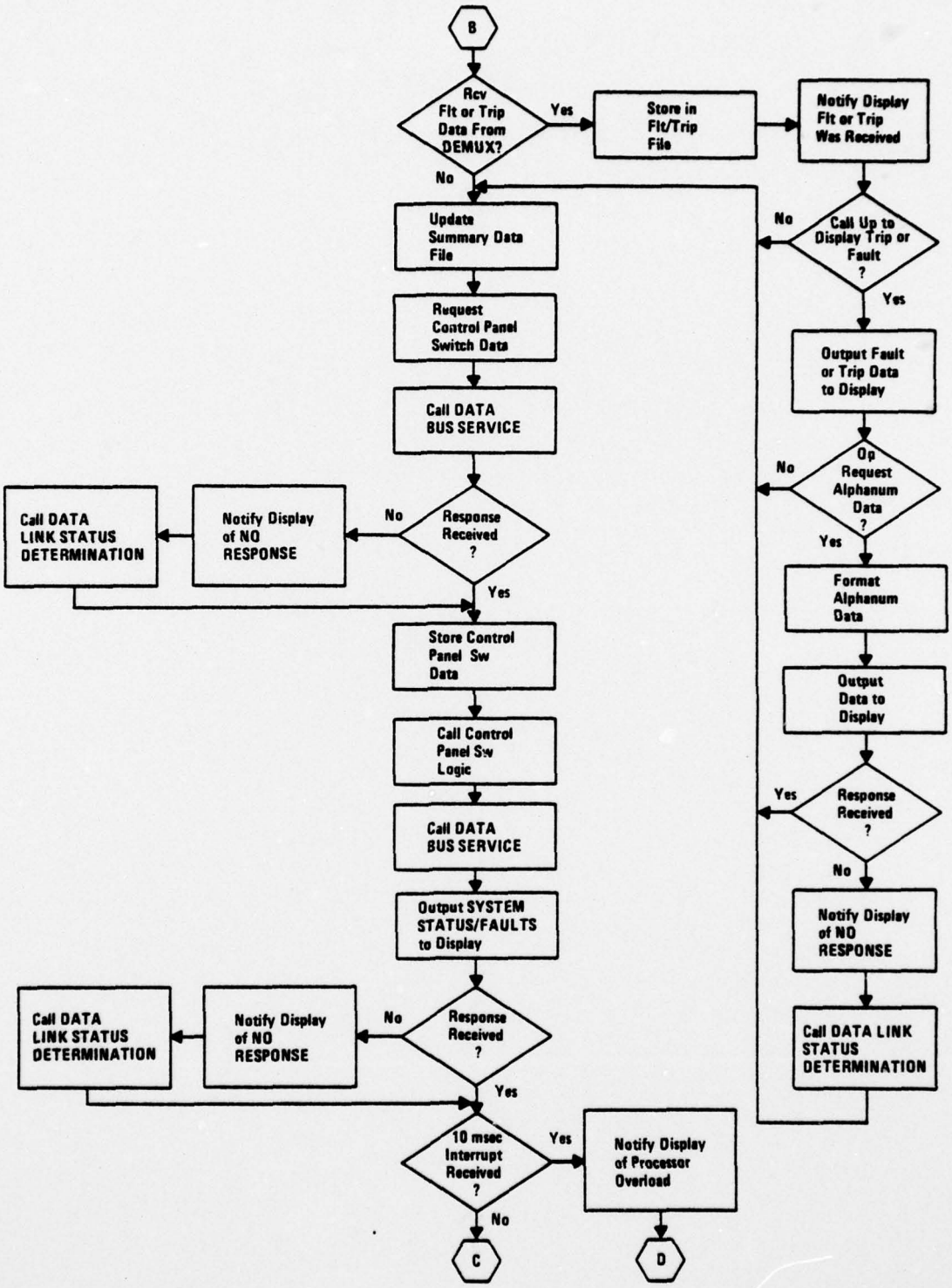


Figure 4-34. F-14 Sostel Processor Flow Diagram (Sheet 3 of 3)

TABLE 4-35. WORST CASE AND AVERAGE PROCESSING TIME (PER MILLISECOND FRAME) (SHEET 1 OF 2)

Subroutine	Update Rate	Worst Case Time, μ sec	Avg Execute Time, μ sec	Worst Case I/O Time, μ sec	Average I/O Time, μ sec
Executive	10 msec	100.98	100.98	—	—
Initialization	1/FLT	—	—	—	—
Self-Test	As Avail	—	—	—	—
System Test	1/GND	—	—	—	—
Data Bus Service	As Req'd	14.00	14.00	—	—
PGS Monitor Data	10 msec	340.00	340.00	—	—
Store PGS Monitor Data	10 msec	—	—	—	—
Output Data to Display	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Load Shed Logic	10 msec	589.56	589.56	—	—
Update Inhibit File	10 sec	13.26	0.0133	—	—
Request Mux Input Data	10 msec	341.36	341.36	1200	1200
Data Bus Service	As Req'd	14.00	14.00	—	—
Output Data to Display	5 sec	340.68	0.68	680	1.36
Data Link Status	Infrequent	61.27	—	140	—
Inhibit Faulted Inputs	10 msec	117.3	117.3	—	—
Output Data to Display	5 sec	62.20	0.12	160	0.32
Output Data to Display	5 sec	62.20	0.12	160	0.32
Format Alplanumerics	5 sec	40.29	0.08	—	—
Output A/N Data to Displays	5 sec	340.68	0.68	680	1.36
Output Data to Displays	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Boolean Processing	10 msec	2198.44	2198.44	—	—
Check Inhibit File	10 msec	407.36	407.36	—	—
Data Bus Service	As Req'd	14.00	14.00	—	—
Output Data to DEMUX	10 msec	545.36	545.36	1920	1920
Data Link Status	Infrequent	61.27	—	140	—
Store In Fault/Trip File	10 msec	—	—	—	—
Output Data to Display	5 sec	62.20	0.12	160	0.32
Output Data to Display	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—

TABLE 4-35. WORST CASE AND AVERAGE PROCESSING TIME (PER MILLISECOND FRAME) (SHEET 2 OF 2)

Subroutine	Update Rate	Worst Case Time, μ sec	Avg Execute Time, μ sec	Worst Case I/O Time, μ sec	Average I/O Time, μ sec
Output Data to Display	5 sec	62.20	0.12	160	0.32
Output Data to Display	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Format Alphanumerics	5 sec	40.29	0.08	—	—
Output A/N Data to Displays	5 sec	340.68	0.68	680	1.36
Output Data to Displays	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Update Summary File	1 sec	1563.36	15.65	—	—
Control Panel Sw Data	10 msec	37.74	37.74	—	—
Data Bus Service	As Req'd	14.00	14.00	—	—
Output Data to Display	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Store Control Panel Sw Data	10 msec	—	—	—	—
Control Panel Sw Logic	10 msec	37.74	37.74	—	—
Data Bus Service	As Req'd	14.00	14.00	—	—
Output System Status/Fault to Display	10 msec	2.38	2.38	60	60
Output Data to Display	5 sec	62.20	0.12	160	0.32
Data Link Status	Infrequent	61.27	—	140	—
Output Data to Display	5 sec	62.20	0.12	160	0.32
Total		8865.29	4907.52	8440	3187.92

Average

Processor Time	49.07%
I/O Time	31.88%

Worst Case

Processor Time	88.65%
I/O Time	84.40%

Input RAM (IRAM)

Mem Addr	Term No. - 16-Bit Data
1	MUX No. 1 Status Word
2	Input Data
3	Input Data
4	Input Data
5	Input Data
46	MUX No. 10 Status Word
47	Input Data
48	Input Data
49	Input Data
50	Input Data

Trip RAM (TRAM)

Mem Addr	Term No. - 16-Bit Data
171	DEMUX No. 1 Status Word
172	Trip Data
173	Trip Data
174	Trip Data
175	Trip Data
236	DEMUX No. 14 Status Word
237	Trip Data
238	Trip Data
239	Trip Data
240	Trip Data

MUX/DEMUX No. 2
PGS Monitor/Load Mgmt File

Mem Addr	Term No. - 16-Bit Data
348	PGS - Status Word
349	Input Data
350	Input Data
351	Input Data
352	Input Data
353	PGS - Status Word
354	Input Faults
355	Input Faults
356	Input Faults
357	Input Faults
358	PGS - Status Word
359	Output Data
360	Output Data
361	Output Data
362	Output Data
363	PGS - Status Word
364	Output Trips
365	Output Trips
366	Output Trips
367	Output Trips
368	PGS - Status Word
369	Output Faults
370	Output Faults
371	Output Faults
372	Output Faults

Summary Data File - (cont)

Mem Addr	Term No. - 16-Bit Data
413	DEMUX No. 1 Output Faults
414	Output Faults
415	Output Faults
416	Output Faults
465	DEMUX No. 14 Output Trips
466	Output Trips
467	Output Trips
468	Output Trips
469	PGS - Input Faults
470	Input Faults
471	Input Faults
472	Input Faults
473	PGS - Output Trips
474	Output Trips
475	Output Trips
476	Output Trips
477	PGS - Output Faults
478	Output Faults
429	Output Faults
480	Output Faults

Transmit Data File

Mem Addr	Word Number
574	Word No. 1
575	Word No. 2
576	Word No. 3
604	Word No. 31
605	Word No. 32
606	Cmd Word

Fault/Trip Address Registers

Mem Addr	Fault/Trip Address
607	Fault Address 1
608	Fault Address 2
609	Fault Address 3
638	Fault Address 32
639	Trip Address 1
640	Trip Address 2
641	Trip Address 3
670	Trip Address 32

Bit RAM (BIRAM)

Mem Addr	Term No. - 16-Bit Data
51	MUX No. 1 Status Word
52	Input Fault
53	Input Fault
54	Input Fault
55	Input Fault
96	MUX No. 10 Status Word
97	Input Fault
98	Input Fault
99	Input Fault
100	Input Fault

Fault RAM (FRAM)

Mem Addr	Term No. - 16-Bit Data
241	DEMUX No. 1 Status Word
242	Fault Data
243	Fault Data
244	Fault Data
245	Fault Data
306	DEMUX No. 14 Status Word
307	Fault Data
308	Fault Data
309	Fault Data
310	Fault Data

Inhibit File

Mem Addr	Term No. - 16-Bit Data
481	DEMUX No. 1 PC Set/Reset
482	PC Set/Reset
483	PC Set/Reset
484	PC Set/Reset
533	DEMUX No. 14 PC Set/Reset
534	PC Set/Reset
535	PC Set/Reset
536	PC Set/Reset
537	MUX/DEMUX No. 2 BC Set/Reset
538	BC Set/Reset
539	BC Set/Reset
540	BC Set/Reset

Scratch Pad

Mem Addr	16-Bit Data
671	Scratch
672	Scratch
770	Scratch

Output RAM (ORAM)

Mem Addr	Term No. - 16-Bit Data
101	DEMUX No. 1 Status Word
102	Output Data
103	Output Data
104	Output Data
105	Output Data
106	DEMUX No. 14 Status Word
166	Output Data
167	Output Data
168	Output Data
169	Output Data
170	

MUX/DEMUX No. 1
Control & Display Panel File

Mem Addr	Term No. - 16-Bit Data
311	Displ - Discrete LEDS
312	Displ - Term No.
313	Alphnum - Wd No. 1 & Wd No. 2
314	Alphnum - Wd No. 3 & Wd No. 4
344	Alphnum - Wd No. 63 & Wd No. 64
345	Switches - Thumb Wheels
346	Switches - Mom, 2 & 3 Position
347	Switches - Rotary

Summary Data File

Mem Addr	Term No. - 16-Bit Data
373	MUX No. 1 Input Faults
374	Input Faults
375	Input Faults
376	Input Faults
409	MUX No. 10 Input Faults
410	Input Faults
411	Input Faults
412	Input Faults

Receive Data File

Mem Addr	Word Number
541	Status Word
542	Word No. 1
543	Word No. 2
544	Word No. 3
572	Word No. 31
573	Word No. 32

Miscellaneous RAM

Mem Addr	16-Bit Data
771	Misc.
772	Misc.
836	Misc.

20% Design Growth

Mem Addr	16-Bit Data
837	Growth
838	Growth
1140	Growth

25% Memory Margin

Mem Addr	16-Bit Data
1141	Spare
1142	Spare
1520	Spare

Figure 4-35. SOSTEL RAM Memory Requirements

Mem Addr	16-Bit Word
1	Executive
2	Executive
150	Executive
151	Initialization
152	Initialization
161	Initialization
162	Data Bus Service
163	Data Bus Service
202	Data Bus Service
203	Req Inputs from MUX
204	Req Inputs from MUX
228	Req Inputs from MUX
229	Rev Flt/Trip from DEMUX
230	Rev Flt/Trip from DEMUX
235	Rev Flt/Trip from DEMUX
236	Output Data to DEMUX
237	Output Data to DEMUX
261	Output Data to DEMUX
262	Boolean Equations
263	Boolean Equations
1616	Boolean Equations
1617	Reqst PGS Data
1618	Reqst PGS Data
1628	Reqst PGS Data
1629	Load Mgmt Priorities
1630	Load Mgmt Priorities
1692	Load Mgmt Priorities
1693	Load Shed Logic
1694	Load Shed Logic
1746	Load Shed Logic
1747	Reqst Sw Data
1748	Reqst Sw Data
1771	Reqst Sw Data

Mem Addr	16-Bit Word
1772	Panel SW Logic
1773	Panel SW Logic
1829	Panel SW Logic
1830	A/N Lookup Table
1831	A/N Lookup Table
10616	A/N Lookup Table
10617	Output A/N Data
10618	Output A/N Data
10663	Output A/N Data
10664	Update Summary File
10664	Update Summary File
10683	Update Summary File
10684	Update Inhibit File
10685	Update Inhibit File
10703	Update Inhibit File
10704	Data Link Status
10705	Data Link Status
10713	Data Link Status
10714	Processor Followup
10715	Processor Followup
10723	Processor Followup
10724	Self-Test
10725	Self-Test
10851	Self-Test
10852	System Test
10853	System Test
10875	System Test
10876	Sys Status & Faults
10877	Sys Status & Faults
10879	Sys Status & Faults
10880	Inhibit Faulted Inputs
10881	Inhibit Faulted Inputs
10903	Inhibit Faulted Inputs

Mem Addr	16-Bit Word
10904	Check Inhibit File
10905	Check Inhibit File
10915	Check Inhibit File
10916	Discrete Data to Display
10917	Discrete Data to Display
10958	Discrete Data to Display
10959	20% Design Growth
10960	20% Design Growth
14943	20% Design Growth
14944	25% Memory Margin
14945	25% Memory Margin
19914	25% Memory Margin

Figure 4-36. SOSTEL Program Fixed Memory Requirements

4.2.3.1 Processor Analysis

This section provides an analysis of SOSTEL processor requirements for the prototype F-14 aircraft.

Each subroutine listed in the previous Table 4-34 "SOSTEL Processor Sizing" is functionally described and evaluated to determine the following:

- No. of words of RAM memory
- No. of words of main program memory
- Subroutine execution time
- Operational duty cycle of each subroutine
- Subroutine operational real time required
- I/O bus transmission time.

Estimates of processor memory size and subroutine execution times are based on current high-speed microprocessor capabilities. The Schottky 3000 bipolar processor is used as a reference of the study. It has a basic 170 nanosecond micro instruction cycle time and a basic instruction set of 100 instructions. An additional 10 microcoded instructions have been devised by Grumman to control one-MBPS multiplexed data bus operations. Five additional microcoded bit addressable instructions are necessary to provide efficient solution to Boolean equations.

Tables 4-36 to 4-39, identify the 3000 processor operating registers, assembly language opcodes, special instructions for bus control, and bit addressable instructions for Boolean processing.

4.2.3.1.1 Executive

This routine steers the SOSTEL processor through the main logic flow of the overall program. It calls various subroutines as required by major program decisions. On application of power, the processor is reset and performs the first subroutine called "initialization." From there it proceeds into the overall processor flow.

TABLE 4-36. "SMART" TERMINAL ASSEMBLY LANGUAGE REGISTER NOMENCLATURE

A	contents of arithmetic register	(R0)
B	contents of buffer register	(R1)
C	contents of counter register	(R2)
I	contents of next word in memory	
L	contents of location counter	(T)
M	contents of memory at location I	
N	contents of memory at location I + C	
P	contents of stack pointer register	(R9)
S	contents of memory at location P	
U	contents of data bus registers	(R3)
V		(R4)
W		(R5)
X	contents of special mask registers	(R6)
Y		(R7)
Z		(R8)

OPCODE Length of significance

1 - character opcodes are reserved for assembler PSEUDO-OPS
2 - character opcodes are processor functions
3 - character opcodes are location counter - program flow instructions
4 - character opcodes are data manipulation functions

TABLE 4-37. BASIC ASSEMBLY LANGUAGE OPCODES (SHEET 1 OF 4)

Opcode	Micro Ops	Words	Function
EI	4	1	Clear Interrupt Inhibit Latch
NO	4	1	No Operation (permit interrupt)
ST	5+	1	Start-up, Load Memory
JMP	6	2	Unconditional Jump to I
JAN	8/9	2	Jump to I If A is neg.
JAP	7/8	2	Jump to I If A is positive (includes 0)
JAZ	7/8	2	Jump to I If A is zero
DBJ	7/8	2	Jump to I If B is zero, else decrement B
DCJ	7/8	2	Jump to I If C is zero, else decrement C
CAL	6	2	Move L into S, increment P, Jump to I
RET	7	1	Decrement P, Jump to S
JLN	7	2	Jump to N
PSHA	6	1	Move A into S, increment P
PSHB	6	1	Move B into S, increment P
PSHC	7	1	Move C into S, increment P
POPA	7	1	Decrement P, Move S into A
POPB	7	1	Decrement P, Move S into B
POPC	7	1	Decrement P, Move S into C
EXSC	9	1	Exchange S and C
LINK *	3	1	No operation (does not permit interrupt)
INT *	8	1	Interrupt

* Available as "micro-subroutines", but not intended for regular program use.

TABLE 4-37. BASIC ASSEMBLY LANGUAGE OPCODES (SHEET 2 OF 4)

Opcode	Micro Ops	Words	Function
ANBA	5	1	AND B with A
ANCA	5	1	AND C with A
ANIA	6	2	AND I with A
ANMA	8	2	AND M with A
ANNA	9	2	AND N with A
ORBA	5	1	OR B with A
ORCA	5	1	OR C with A
ORIA	6	2	OR I with A
ORMA	8	2	OR M with A
ORNA	9	2	OR N with A
XNBA	5	1	Exclusive OR B with A
XNCA	5	1	Exclusive OR C with A
XNIA	6	1	Exclusive OR I with A
XNMA	8	2	Exclusive OR M with A
XNNA	9	2	Exclusive OR N with A
ONEA	4	1	One's complement A
TWOA	5	1	Two's complement A
ONEB	4	1	One's complement B
TWOB	5	1	Two's complement B
ADAB	6	1	Add A to B
ADAC	6	1	Add A to C
ADAM	8	2	Add A to M
ADAN	9	2	Add A to N
ADIA	7	2	Add I to A
ADIB	7	2	Add I to B
ADIC	7	2	Add I to C

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ADVANCED AIRCRAFT ELECTRICAL SYSTEM (AAES). DEFINITION AND PROT--ETC(U)
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TABLE 4-37. BASIC ASSEMBLY LANGUAGE OPCODES (SHEET 3 OF 4)

Opcode	Micro Ops	Words	Function
SUAB	7	1	Subtract A from B
SUAC	7	1	Subtract A from C
INRA	4	1	Increment A
INRB	4	1	Increment B
INRC	4	1	Increment C
INRM	7	2	Increment M
INRN	8	2	Increment N
R5AA	10	1	Shift A alone right 5 places
R3AA	8	1	Shift A alone right 3 places
R1AA	6	1	Shift A alone right 1 place
L5AA	10	1	Shift A alone left 5 places
L3AA	8	1	Shift A alone left 3 places
L1AA	6	1	Shift A alone left 1 place
R1AB	10	1	Shift A and B right 1 place
L1AB	10	1	Shift A and B left 1 place
EXAB	9	1	Exchange A and B
EXAC	9	1	Exchange A and C
EXAM	10	1	Exchange A and M
EXAN	12	1	Exchange A and N
EXBC	9	1	Exchange B and C
MVBA	5	1	Move B into A
MVCA	5	1	Move C into A
MVIA	6	2	Move I into A
MVMA	8	2	Move M into A
MVNA	9	2	Move N into A
MVAB	5	1	Move A into B
MVCB	5	1	Move C into B

TABLE 4-37. BASIC ASSEMBLY LANGUAGE OPCODES (SHEET 4 OF 4)

Opcode	Micro Ops	Words	Function
MVIB	6	2	Move I into B
MVMB	8	2	Move M into B
MVNB	9	2	Move N into B
MVAC	5	1	Move A into C
MVBC	5	1	Move B into C
MVIC	6	2	Move I into C
MVMC	8	2	Move M into C
MVPC	5	1	Move P into C
MVCP	5	1	Move C into P
MVAM	7	2	Move A into M
MVBM	7	2	Move B into M
MVCM	7	2	Move C into M
MVAN	8	2	Move A into N
MVBN	8	2	Move B into N
MVAU	5	1	Move A into U
MVBV	5	1	Move B into V
MVCW	5	1	Move C into W
MVAX	5	1	Move A into X
MVBY	5	1	Move B into Y
MVCZ	5	1	Move C into Z
MVUA	5	1	Move U into A
MVVB	5	1	Move V into B
MVWC	5	1	Move W into C
MVXA	5	1	Move X into A
MVYB	5	1	Move Y into B
MVZC	5	1	Move Z into C
INNA	TBD	2	Input from port I to A
OUTB	TBD	2	Output to port I from B

TABLE 4-38. SPECIAL BUS ORIENTED CONTROL INSTRUCTIONS

MVA3	Store A in the internal "next output word" register
MVA4	Store A in the internal "own address" register
MVA5	Store A in the internal "address mask" register
MVA6	Store A in the internal "MODE-COUNT" register
MVA7	Store A in spare internal register
MVA8	Store A in spare internal register
XMIT	Output the contents of the "next output word" register to the bus buffer from which the last honored command was received.
TAD	Test the address field of an incoming message against the internal address register using the internal address word; jump to the contents of I if they do not match.
SRC5	Shift the contents of the C register right five places
TDB	Test the mode and count fields of an incoming message using the internal mode-count mask; jump to the contents of I if the content of the field is zero.

TABLE _ Bit Addressable Instructions For Boolean Processing

FBIT	Fetch a bit as defined by bit number and bit address in instruction word.
ABIT	Combines FBIT with logical "and" of data bit in A reg. and accumulator. Stores result in A reg.
OBIT	Combines FBIT with logical "or" of data bit in A reg. and accumulator.
NABIT	Combines FBIT with logical "and" of data bit in A reg. and complement of accumulator bit.
NOBIT	Combines FBIT with logical "or" or data bit in A reg. and complement of accumulator bit.

RAM Required (Scratch Pad Only)

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Jump to "Initialization"	2	6	1.02
Jump to "Self Test"	2	6	1.02
Test "Airborne" or "Ground Ops"	1	7	1.19
Jump to "System Test"	2	8	1.36
Call "Data Bus Service"	2	6	1.02
Jump "PGS Monitor Data & Store"	2	6	1.02
Test "Response Received"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status Determination"	2	6	1.02
Test "On Motor/Gen Power"	1	7	1.19
Jump to "Load Shed Logic"	2	8	1.36
Call "Load Mgmt Priorities"	2	6	1.02
Jump to "Update Inhibit File"	2	6	1.02
Jump "Request Input Data"	2	6	1.02
Call "Data Bus Service"	2	6	1.02
Test "Response Received"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status"	2	6	1.02
Test Input or Fault Data	1	7	1.19
Jump to "Inhibit Faulted Inputs"	2	8	1.36
Call "Output Data to Displays"	2	6	1.02
Test "Operator Call Displays"	1	7	1.19
Jump to "Output Data to Displays"	2	8	1.36
Test "Operator call for Alphanumerics"	1	7	1.19
Jump "Format Alphanumerics"	2	8	1.36
Call "Output Data to Displays"	2	6	1.02

	16 Bit Words	Micro-Ops	Time, usec
Test "Response Received"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status"	2	6	1.02
Jump "Boolean Processing"	2	6	1.02
Call "Check Inhibit File"	2	6	1.02
Call "Data Bus Service"	2	6	1.02
Jump "Output Data to Demux"	2	6	1.02
Test "Response Received"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status"	2	6	1.02
Test "Fault or Trip from Demux"	1	7	1.19
Jump "Store in Fault/Trip File"	2	8	1.36
Call "Output Data to Displays"	2	6	1.02
Test "Response Received"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status"	2	6	1.02
Test "Operator Call for Alphanumerics"	1	7	1.19
Call "Output Data to Displays"	2	6	1.02
Test "No Response"	1	7	1.19
Notify Display of "No Response"	5	20	3.40
Call "Data Link Status"	2	6	1.02
Jump "Store Control Panel Sw Data"	2	8	1.36
Jump "Control Panel Sw Logic"	2	8	1.36
Call "Data Bus Service"	2	6	1.02
Jump "Output System Status/Fault Display	2	6	1.02
Test "No Response"	1	7	1.19
Notify Display of "No Response"	5	20	3.40

	16 Bit Words	Micro-Ops	Time, usec
Call "Data Link Status"	2	6	1.02
Test "10 M Sec Interrupt Received"	1	7	1.19
Notify Display of "Processor Overload"	5	20	3.40
Jump to either "Self Test" or Airborne"	2	8	1.36
	150		100.98

150 words of program memory required.

Subroutine Execution Time

100.98 usec per frame

Operational Duty Cycle

Every 10 msec

Total Processor Time Required

100.98 x 100 = 10,098 usec/sec

4.2.3.1.2 Initialization

This subroutine is always used following application of power to the processor. It is applied on initial power-up by either external power or main generator power in-flight; also, it is assummed that power is maintained on the processor (via batteries) until the motor-generator set is up to speed. This preserves whatever data is located in volatile RAM memories.

On application of power, the subroutine basically "safes" or de-energizes all output loads and zeros all processor files to eliminate random bit patterns in RAM memory. The following RAM files are affected during initialization:

	No. Words RAM
"Safe" or de-energize all loads	70
Input fault and status word file	90
Output fault, trip and status word file	140
Control panel switch data	3
Display data file	33
Summary data file	164
Inhibit data file	60
Receive data file	33
Transmit data file	33
PGS monitor data	25
	651

RAM Required

(None)

Program Memory Required

This routine requires zeroing a register, addressing memory, then moving the zero contents of the register to RAM memory and repeating the sequence until all files have been zeroed.

		16 Bit Words	Micro-Ops	Time, usec
	Zero A Register	1	7	1.19
	Set init mem addr	2	10	1.70
Repetitive	Move A into M	2	7	1.19
	Increment M	2	7	1.19
	Check counter	2	8	1.36
	JMP	2	6	1.02

Subroutine Execution Time

Repetitive operation time	= 3.74 usec
No. words to be zeroed	= 651
Total iteration time	= 2435 usec
Non repetitive operations	= 3.91 usec
Subroutine execution time	= 2439 usec

Operational Duty Cycle

At power up only - once per flight

Total Processor Time Required

2439 usec per flight

I/O Time

(None)

4.2.3.1.3 Data Bus Service

This routine is required whenever a data and/or a control word is transmitted by the processor, or data and/or a status word is received by the processor from MUX, DEMUX, or MUX/DEMUX terminals. It controls data to or from the bus and routes data from or to the transmit or receive data files. These files have a maximum capability of 33 words, command and 32 data words, status and 32 data words.

RAM Required

Transmit Data File	-	33 x 16 Bit Words of RAM
Receive Data File	-	33 x 16 Bit Words of RAM

Program Memory Required

	Words	Micro-Ops	Time, usec
Data Bus Service	41	82	14

41 x 16 Bit Words of Program Memory

(41 words are required based on actual programming of this function)

Subroutine Execution Time

14 usec (each use)

Execution time has been included as part of each calling subroutine, therefore, no real time or I/O time is included here.

4.2.3.1.4 Request Input or Fault Data From MUX

This routine performs the function of setting up a transmit command control word with specific MUX terminal addresses and control bits to request either transducer input or fault data. It steers the responding terminals data to appropriate memory locations for storage and evaluates the returned terminal status word.

RAM Required

90 X 16 Bit Words

Program Memory Required

	16 Bits Words	Micro-Ops	Time, usec	
Fetch MUX Terminal Address	2	8	1.36	Fix
Load Addr to Control Word	2	8	1.36	Fix
Set 6 Control Bits (6 Fetch Bit)	12	72	12.24	Fix
Set up Mem Addr for Response data or faults	2	8	1.36	Iter
Increment Start Addr	1	4	0.68	Iter
Test End of Data	2	8	1.36	Iter
Increment MUX Addr	1	4	0.68	Fix
Test end of MUX Addr	2	8	1.36	Fix
JMP Exec or Panel Switches	2	8	1.36	
	26			

26 Fixed Program Words Required

Subroutine Execution Time

(1) For one MUX Terminal

Fixed Part	=	17 usec
Iterative Part	=	17 usec (5 Iterations)
		34 usec per terminal

(2) For 10 MUX Terminals

10 (34.0) + 1.36 = 341.36 usec

This is the processor time required to request input data or input faults.

Operational Duty Cycle

Sample all MUX Terminals once every 10 msec

Total Processor Time Required

34,136 usec/sec

I/O Time

Send transmit control word to MUX	=	20 usec
Receive status and 4 Data Words	=	100 usec
(per terminal)		120 usec

1,200 usec for 10 MUX terminals/frame or

120,000 usec/sec. Figure 4-37 illustrates the availability of processing time during a received word period.

4.2.3.1.5 Receive Fault or Trip Data From DEMUX

This routine controls the storage in memory of trip or fault data and the corresponding status word received from a DEMUX terminal. This information is assumed to be transmitted to the processor only when trip or fault data has changed in the DEMUX

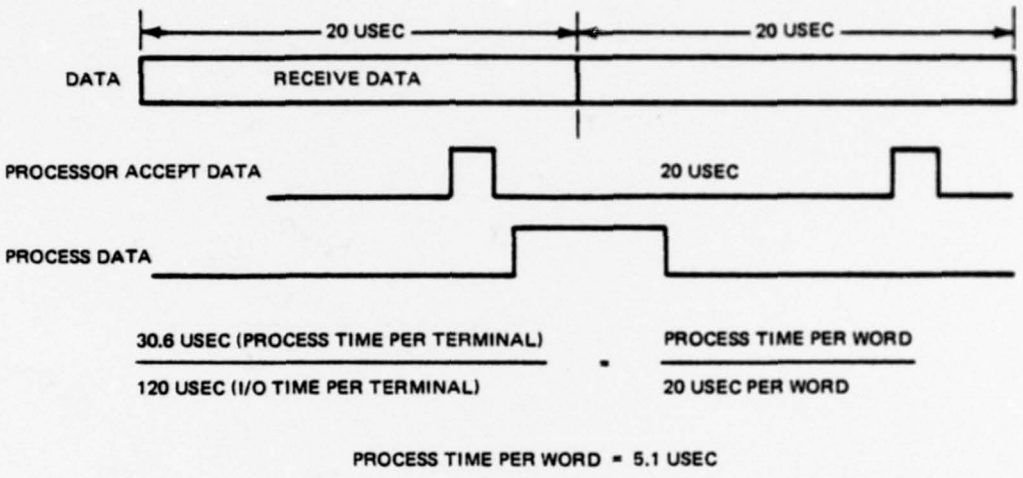


Figure 4-37. I/O and Some Processing Time Overlap

terminal. The duty cycle associated with this subroutine is, therefore, much lower than the nominal frame rate.

RAM Required 140 x 16 Bit Words

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Set up Memory address for trip or fault data	2	8	1.36 Fix
Increment Start Addr	1	4	0.68 Iter
Test End of Data	2	8	1.36 Iter
JMP out	2	8	1.36 Fix
	7		

7 fixed program words required.

Subroutine Execution Time

(1) For one DEMUX Terminal

Fixed Part = 2.72 usec

Iterative Part = 10.20 usec (5 Iterations)

12.92 usec per terminal

This is processor time required to accept trip or fault data from one terminal

Operational Duty Cycle

The duty cycle of reporting faults and trip data can only be assumed at this time. For purposes of this analysis, we will conservatively assume that one DEMUX terminal reports either trip or fault data during over a one-second period. Thus, for each 10-Msec frame period, 12.92 usec are required by the processor during receipt of trip or fault data from one DEMUX terminal.

Total Processor Time Required

12.92 usec/sec

I/O Time

Receive DEMUX Status Word	20 usec
Receive 4 Trip or Fault words	80 usec
	100 usec

100 usec/sec

4.2.3.1.6 Output Data to DEMUX and MUX/DEMUX

This routine controls the output of Boolean equation solutions to DEMUX terminals to set or clear power controllers.

RAM Required

Solutions to Boolean equations are stored in 70 x 16 Bit RAM locations.

Program Memory

	16 Bit Words	Micro-Ops	Time, usec	
Fetch MUX Terminal Address	2	8	1.36	Fix
Load Addr to Control Word	2	8	1.36	Fix
Set 6 Bits (Fetch Bit)	12	72	12.24	Fix
Set Mem Addr for Data	2	8	1.36	Iter
Increment Mem Addr	1	4	0.68	Iter
Test End of Data	2	8	1.36	Iter
Increment MUX Addr	1	4	0.68	Fix
Test End of MUX Addr	2	8	1.36	Fix
JMP out	2	8	1.36	
	26			

26 fixed program words required.

Subroutine Execution Time

(1) For 1 DEMUX Terminal

Fixed Part = 17 usec

Iterative Part = 17 usec (5 iterations)

34 usec/terminal

(2) For 14 DEMUX Terminals and 2 MUX/DEMUX Terminals

16 (34.0) + 1.36 = 545.36 usec/frame

Operational Duty Cycle

All DEMUX terminals update once per 10-msec frame

Total Processor Time Required

54,536 usec/sec

I/O Time

Send receive control word to DEMUX = 20 usec

Send four ourput data words = 80 usec

Receive status word = 20 usec

120 usec (per terminal)

1920 usec for 16 DEMUX and MUX/DEMUX terminals/frame or

192,000 usec/sec

4.2.3.1.7 Boolean Equation Processing

Equation forms for the F-14 were tabulated and prorated to arrive at a baseline for analysis of the processor requirements for Boolean equation processing. The technique for arriving at the quantities is as follows:

Boolean Equations

1) 544 tabulated

2) Prorating based on 82% complete and 20% growth

$$\frac{544}{(082)} \times 1.2 = 796 \approx 800 \text{ total}$$

3) 27% $\frac{(149)}{(544)}$ are zero term equations which do not require solutions

4) 73% $\frac{(395)}{(544)}$ are non-zero term equations

5) Prorating the total based upon 73% non-zero equations

$0.73 \times 800 = 584$ total equation requiring solutions

6) Prorating the various equation forms as tabulated in Table 4-40

RAM Required

Boolean equations solutions are stored in 70 x 16 bits of RAM memory.

Program Memory Required

Boolean operations are based on the use of bit addressable assembly language instructions, FBIT, ABIT, OBIT, NABIT, NOBIT.

The form of the Boolean equations is represented as the sum of groups of product. (e.g., $A = B \cdot C + D \cdot E$). One 16-bit instruction word is required for each term in the equation and another is required for each group of products. The former represents bit addressable logic functions while the latter is a test or jump instruction used after each product group is logically formed.

TABLE 4-40. BOOLEAN EQUATION FORMS (SHEET 1 OF 2)

Qty	No. Of Term	No Of Prod	Logic Equation Form
152	1	1	A = B
36	2	1	A = B•C
23	2	2	A = B+C
16	3	1	A = B•C•D
9	3	2	A = B+C•D
7	4	2	A = B•C+B•D
10	3	3	A = B+C+D
10	4	1	A = B•C•D•E
3	4	2	A = B•C+D•E
8	6	2	A = B•C•D+B•C•E
1	4	2	A = B+C•D•E
4	5	3	A = B+C•D+C•E
4	6	3	A = BC+BD+BE
2	4	3	A = B+C•D+E
3	8	4	A = BD+BE+CD+CE
9	5	1	A = B•C•D•E•F
2	8	2	A = BCDE+BCDF
2	7	2	A = BCD+BCEF
1	7	3	A = BC+BD+BEF
1	6	3	A = BC+DE+DF
1	6	3	A = B+CD+EF
1	12	4	A = BCE+BDE+BCF+BDF
1	6	1	A = B•C•D•E•F•G
2	6	2	A = B+C•D•E•F•G
1	6	2	A = B•C•D+E•F•G
1	16	4	A = B•D•F•G+B•E•FG+C•D•F•G+C•E•FG
2	9	2	A = B•C•D•E+B•C•D•FG
1	12	3	A = B•D•D•E+B•C•D•F+B•C•D•G
1	9	3	A = B+C•D•E•F+C•D•E•G
1	8	3	A = B•C+D•E•F+D•E•G
2	10	5	A = B•C+B•D+B•E+B•G+BG

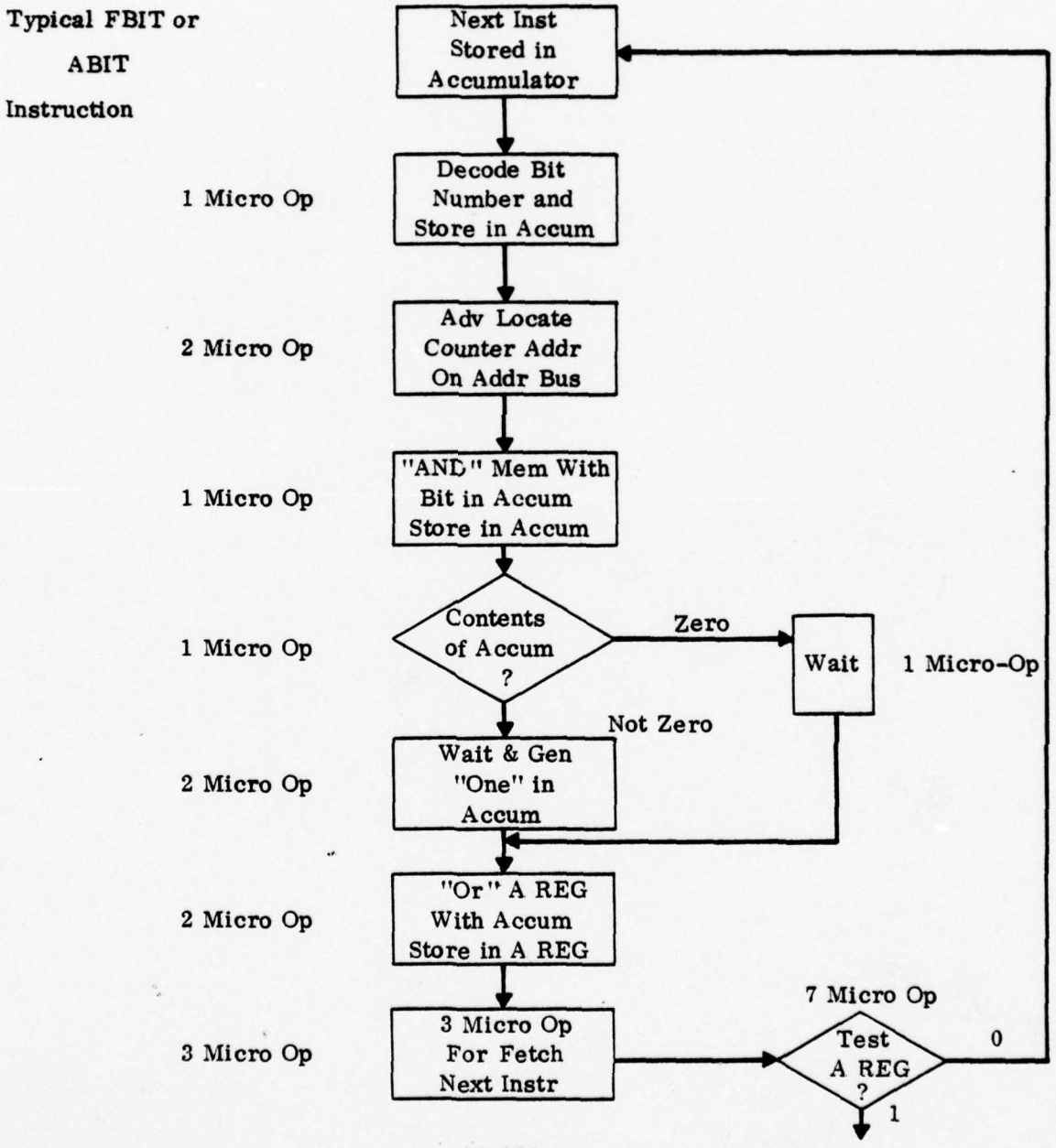
TABLE 4-40. BOOLEAN EQUATION FORMS (SHEET 2 OF 2)

Qty	No. Of Term	No. Of Prod	Logic Equation Form
2	32	8	A = B(C+D) (E+F) (G+H)
1	25	9	A = B+ [(C+D) (E+F) (G•H)]
1	9	5	A = B+C+D+E•F (G+H)
1	11	3	A = B•C•D•E+B•C•D•F+G•H•I
1	28	10	A = B(C+D+E) (F+G+H)+I
1	11	3	A = B(C+D•E+F•G+H•I)
2	10	4	A = B+C•D•D+F•G•I+F•G•H
2	12	6	A = B+C•D+C•E+C•H+C•I+C•F•G
2	20	10	A = (B+C+D) (E+F)+(G+H) (I+J)
1	14	5	A = B(C+D•E+F•G+F•H+I•J)
1	13	6	A = B+C+D+E•I•J+F•I•J+G•H•I•J
1	12	3	A = B•C•D•E+B•C•D•F+F•H•I•J
1	36	12	A = B(C+D) (E+F+G+H+I+J)
1	36	12	A = (B+C+D+E) (D•E+F•G+H•I)
1	30	9	A = (B+C+D•E) (F•G•H+I+J•K)
1	16	4	A = B(C+D)+(E+F) (G•H•I•J•K)
1	12	5	A = B+C•D+E•F•G•H+I(J+K•L)
2	12	7	A = B+C•D+E•F+G+H+I•J+K+L•M
1	56	12	A = B(C+D+E+F•G+H+I) (J+K•L)M
1	12	6	A = B+C+D•E+F+G•H•I•J+K•L•M
1	50	18	A = (B+C) (D+E+F•G+F•H+I•J+ [K+L] [M+N])
1	61	16	A = (B+C+D•E) ([F+G+H+I] J•K+L)+M•N
1	21	11	A = B+C (D+E+F+G+H) + I (J+K+L+M+N)
1	77	27	A = B+[C+(D+E+F+G) (H+I+J)][K+L]
1	44	16	A = (B+C) (D•E+F•G+J+I)+(J+K) (L+M) (N+O)
1	19	3	A = B•C•D•E(F+G) +H•I•J•K•L•M•N•O•P
2	40	14	A = B(C+D+E) (F+G+H)+(I+J)K•L•M+N•O•P+Q+R
1	21	3	A = B•C•D•E (F+G)+H•I•J•K•L•M•N•O•P•Q•R
1	52	10	A = (B+C)D+(E+F)GHI+J•K•K•L•M•N+O•P•Q•R•S•T (U+V+W=X=Y)
12	53	6	A = B+C•D•E•F•G+H+I•J•L•M•N•O+P•Q•R•S•T•U•V•W•X +Y•Z•A_1•B_1•C_1•D_1•E_1•F_1•G_1•H_1•I_1
	1017	838	

Typical Bit Addressable Instructions

FBIT - Fetch a Bit as defined by bit number and bit address in the instruction word.

ABIT - Combines FBIT with logical "AND" of data bit in A REG and accumulator. Stores result in A REG.



The number of program words required to solve the Boolean Equations is therefore, the sum of the number of terms and products for each equation form.

$$M_P = \sum (T + P)$$

M_P = No. of 16 Bit program memory words

T = No. of terms in logic equations

P = No. of product terms

From Table 4-40 T = 1017 & P = 338

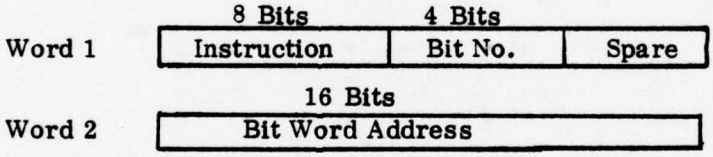
$$M_P = 1017 + 338 = 1355 \text{ words}$$

Operational Duty Cycle

10-msec frame rate

Total Processor Time Required

The time required to solve F-14 equations is based on the special bit addressable instructions which are formulated by means of micro-program code. The instructions consist of two 16-bit words organized as follows.



There are 12 micro-ops required to mechanize basic FETCH BIT, AND BIT, OR BIT instructions. Each micro cycle corresponds to 170 nanosec. Testing the resulant information in the A Register requires a conditional Jump instruction which takes seven or eight microcycles.

Instruction	Microcycles	Time Required, usec
FETCH BIT	12	2.04
AND BIT	12	2.04
OR BIT	12	2.04
AND $\overline{\text{BIT}}$	12	2.04
OR $\overline{\text{BIT}}$	12	2.04
JUMP	8	1.36

With the above information it is now possible to estimate the time required to solve the SOSTEL Boolean equations for the F-14A. The approach to handling the Boolean equations is to format each equation into groups of "OR'D" products. For example:

A = B (C + D) (E + F) may be rewritten as;

$A = B \cdot C \cdot E + B \cdot D \cdot E \cdot + B \cdot C \cdot F + B \cdot D \cdot F$

The program sequence would be to Fetch B, "AND" C, "AND" E, test for zero. If the product BCD is non-zero, the equation is satisfied and no further terms need be evaluated. If the test results in a zero condition the next group of products is then evaluated.

This approach to logic equation solution implies that a Fetch, AND or OR instruction is required for every term in the equation. Also a test or jump is required for each product term in the equation.

Solution time is therefore;

$$t_{sol} = 2.04 \sum TxQ + 1.36 \sum PxQ$$

t_{sol} = Equation solution time in usec/frame

2.04 = usec per Fetch or Logic Instruction

T = No. terms in logic equation

Q = No. of equations of each type

1.36 = usec per test instruction

P = No. of product terms

t_{sol} = 2.04 x 3402 + 1.36 x 1363 usec

6940.08 + 1853.68

t_{sol} = 8797.6 usec/frame

Since the probability of MUX inputs changing is uniformly distributed (equal probability of changing), then on the average we only have to check half the equation terms to get a solution. Therefore, the time is one-half of the foregoing number. In addition to this, the inputs are roughly divided into 50% manually operated cockpit switches, and 50% automatically operated input functions. The rate at which manual switches are operated (say one every 10 sec) represents a negligible contribution to Boolean processing time. The automatic input functions are assumed to all change every 10-Msec frame. This is very conservative and in reality should be much less, but will be used for processor sizing purposes.

Average solution time per frame = 2198.44 usec

Total solution Time = 219,844 usec

I/O Time None

Time to Store Boolean Solutions in RAM

This time estimate is based on the instruction execution time required, to move data from a register to a memory location whose address is specified by a memory address register. MVAM instruction (move A into M) requires seven micro ops to execute. This equates 7 x 170 or 1190 nanoseconds per word of RAM storage, 70 words of RAM are needed to store Boolean solutions. Time to store 70 words in RAM is therefore 83.3 usec.

4.2.3.1.8 Request PGS Monitor Data

This subroutine requests, stores, and examines monitor data (or PGS fault data). Another routine "Load Shed Logic" provides the function of executing PGS data by taking appropriate action to control bus controllers and shed power controller loads according

to PGS status. The PGS monitor data is acquired from MUX/DEMUX terminal No. 02R which has been dedicated to PGS interface functions.

RAM Required

To store all PGS related data (inputs, outputs, input faults, output faults, trips and status words) 25 x 16 bits of RAM are necessary.

Program Memory Required

PGS Monitor data is requested by means of a control word transmitted to the PGS MUX/DEMUX. Returned status and four data words are examined for condition of the PGS monitor signals. A maximum of 64 PGS input bits are examined for their state. An alternate 64 bits are examined whenever fault data is returned to the processor by the MUX portion of the PGS terminal. Returned data or fault bits are individually checked. If a PGS bit is set, load shed logic routine is called after which program control is returned to this routine.

	16 Bit Words	Micro-Ops	Time, usec	
Set initial word and bit Address	2	10	1.70	Fix
Fetch Bit and test	2	10	1.70	
Call Load Shed Logic	2	6	1.02	
Increment Addr	2	7	1.19	
Test Index for Last Addr	2	8	1.36	
Jump to Load Shed Logic	2	6	1.02	Fix

12 fixed program words required.

Subroutine Execution Time

Fixed Part	=	2.72 usec
Iterative Part 5.27 x 64	=	337.28 usec
		340.00 usec

Operational Duty Cycle

10 msec

Total Processor Time Required

34,000 usec/sec

I/O Time

Send transmit command	20 usec
Receive MUX/DEMUX Status Word	20 usec
Receive 4 input or fault words	80 usec
	120 usec

120 usec/frame

12,000 usec/sec

4.2.3.1.9 Load Shed Logic

Load shed logic basically accepts checked PGS monitor signals, controls bus controllers and enables power controllers according to the capacity of the available power generating systems. The load shed management concept is simply defined as follows: If left and right generators are functioning all aircraft loads are permitted on both a-c and d-c buses. If both left and right generators are out, the hydraulically driven motor/generator supplies both a-c and d-c power with limited capacity. Load sheding is necessary when operating on the motor generator set, and is based on the load management priorities stored in the processor.

Load shed logic accepts PGS monitor bits which have been set, solves the load shed logic equations, and updates the load management bus controller and power controller inhibit files accordingly. Figure 4-38 illustrates the load shed logic flow.

RAM Required

(None)

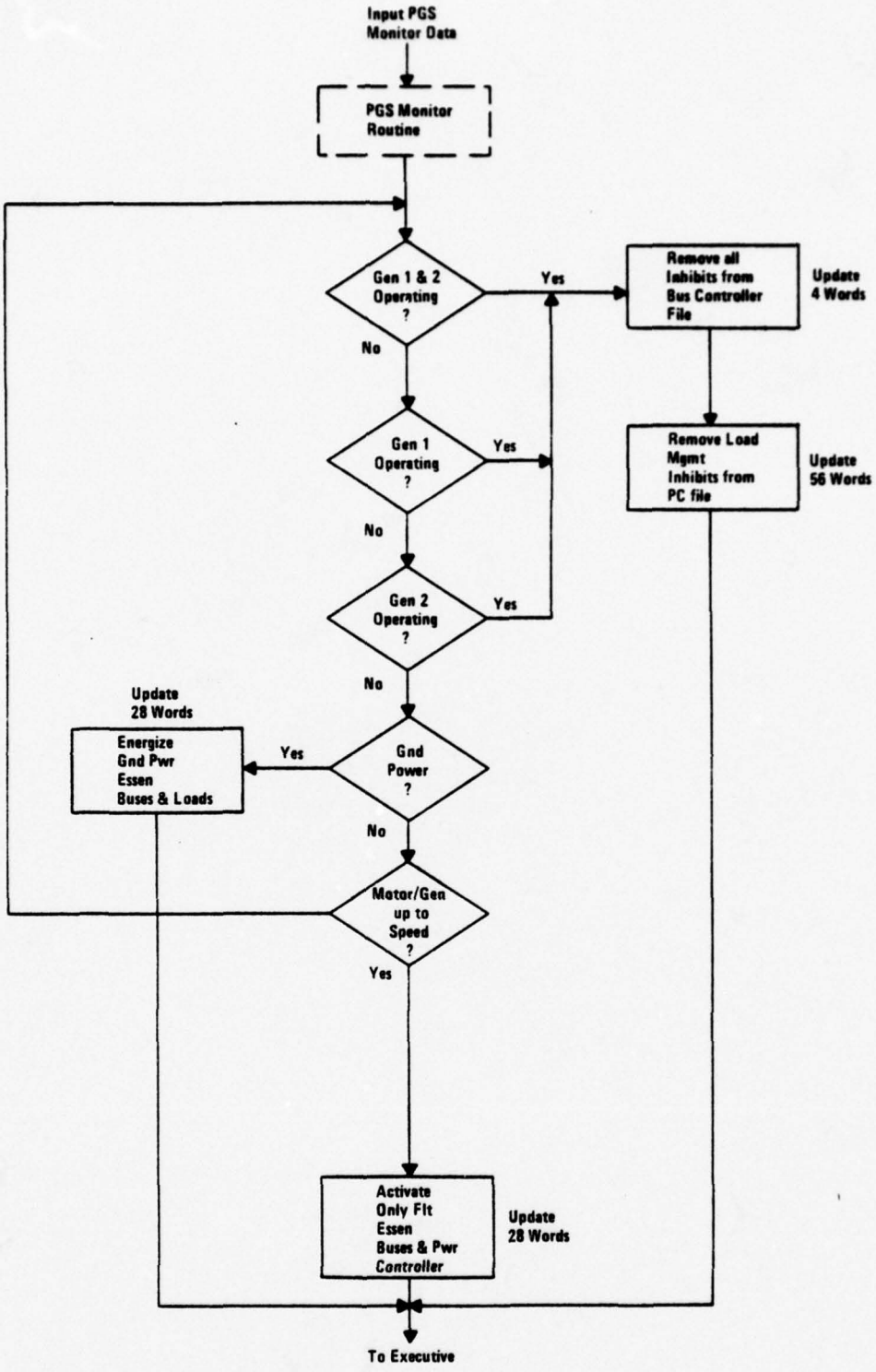


Figure 4-38. Load Shed Logic Flow Diagram

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec	
(Load Routine)				
Set Initial Memory Address	2	10	1.70	Fix
Load A Register	1	7	1.19	Iter
Move A into M	2	7	1.19	Iter
Incr M	2	7	1.36	Iter
Check Addr Counter	2	8	1.36	Iter
Jump	2	6	1.02	Fix
(Logic - using above routine for loading)				
5 test/jump conditions	10	40	6.80	
(4 Wds) Remove inhibits from BC file	11	-	22.44	
(45 Wds) Remove inhibits from PC File	11	-	278.80	
(28 Wds) Energize Gnd Pwr Essn Loads	11	-	140.76	
(28 Wds) Activate Flt Essn Buses and Loads	11	-	140.76	
	54		598.56	usec

Total program memory 54 x 16 bit words.

Subroutine Execution Time

589.56 usec/frame

Operational Duty Cycle

10 msec

Total Processor Time

58,956 usec/sec

I/O Time

Included in "output data to DEMUX & MUX/DEMUX"

4.2.3.1.10 Request Control Panel Switch Data

This routine controls the issuance of a control word to the control/display panel requesting that current panel switch data be returned to the processor. Figure 4-39 illustrates the panel switch data transmitted to the processor.

RAM Required

Three words required to store panel switch data.

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Fetch MUX/DEMUX No. 01R Terminal Address	2	8	1.36
Load Addr to Control Word	2	8	1.36
Set 6 Control Bits	12	72	12.24
Setup RAM Addr for sw Data	2	8	1.36
Move Data to RAM	2	8	1.36
Increment Memory Addr	1	4	0.68
Test End of Data	2	8	1.36
Jump to Exec	2	8	1.36
	25		

25 x 16 bit program words required.

Subroutine Execution Time

Fixed Part	=	16.32 usec
Iterative Part	=	19.04 usec
		35.36 usec

35.36 usec per frame

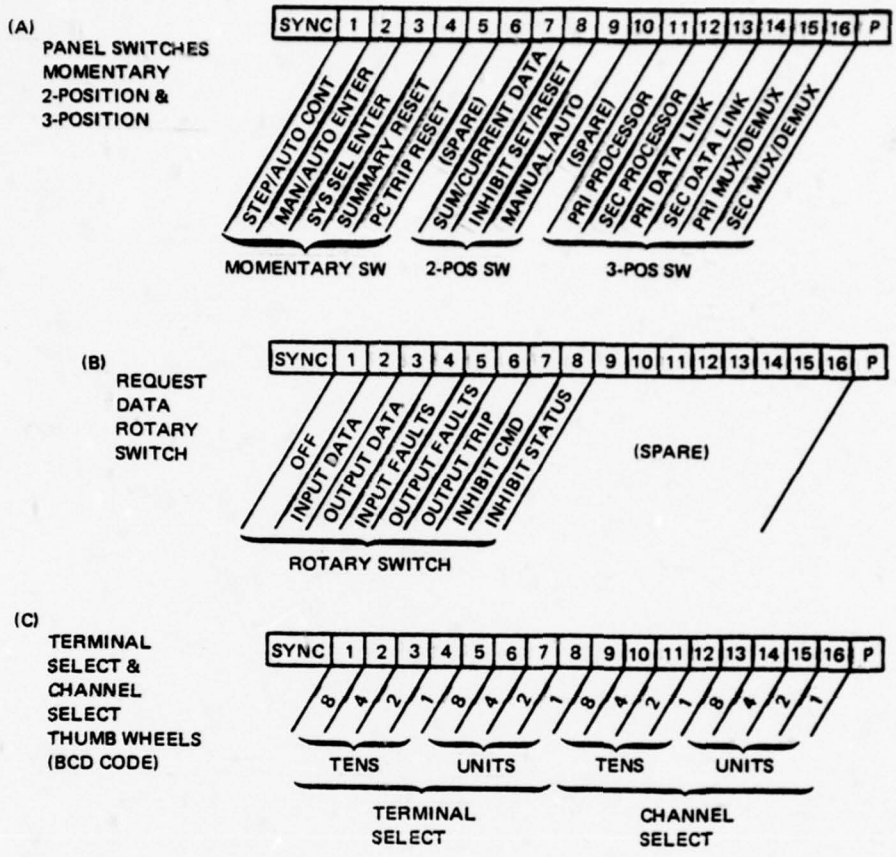


Figure 4-39. CCDP Data Words Transmitted-to-Processor

Operational Duty Cycle

10 msec

Total Processor Time Required

3536 usec per sec

I/O Time

Transmit control word to MUX/DEMUX No. 01R	20 usec
Receive three words of switch data	60 usec
Receive Status word	20 usec
	100 usec

I/O time per frame is 100 usec

Total I/O Time is 10,000 usec/sec

4.2.5.1.11 Control Panel Switch Logic

Control panel switch logic (see Fig. 4-40) solves basic switch interlock logic. It either calls up requested data for display or feeds control information to the processor for other purposes (e.g., inhibit, link select, processor select). The switch logic provides two functions:

(1) System Select - switch command from the panel used to select primary or secondary data link, processor, or redundant terminal elements.

(2) Data Select - switch commands from the panel which request that specific types of data be displayed.

RAM Required

(None)

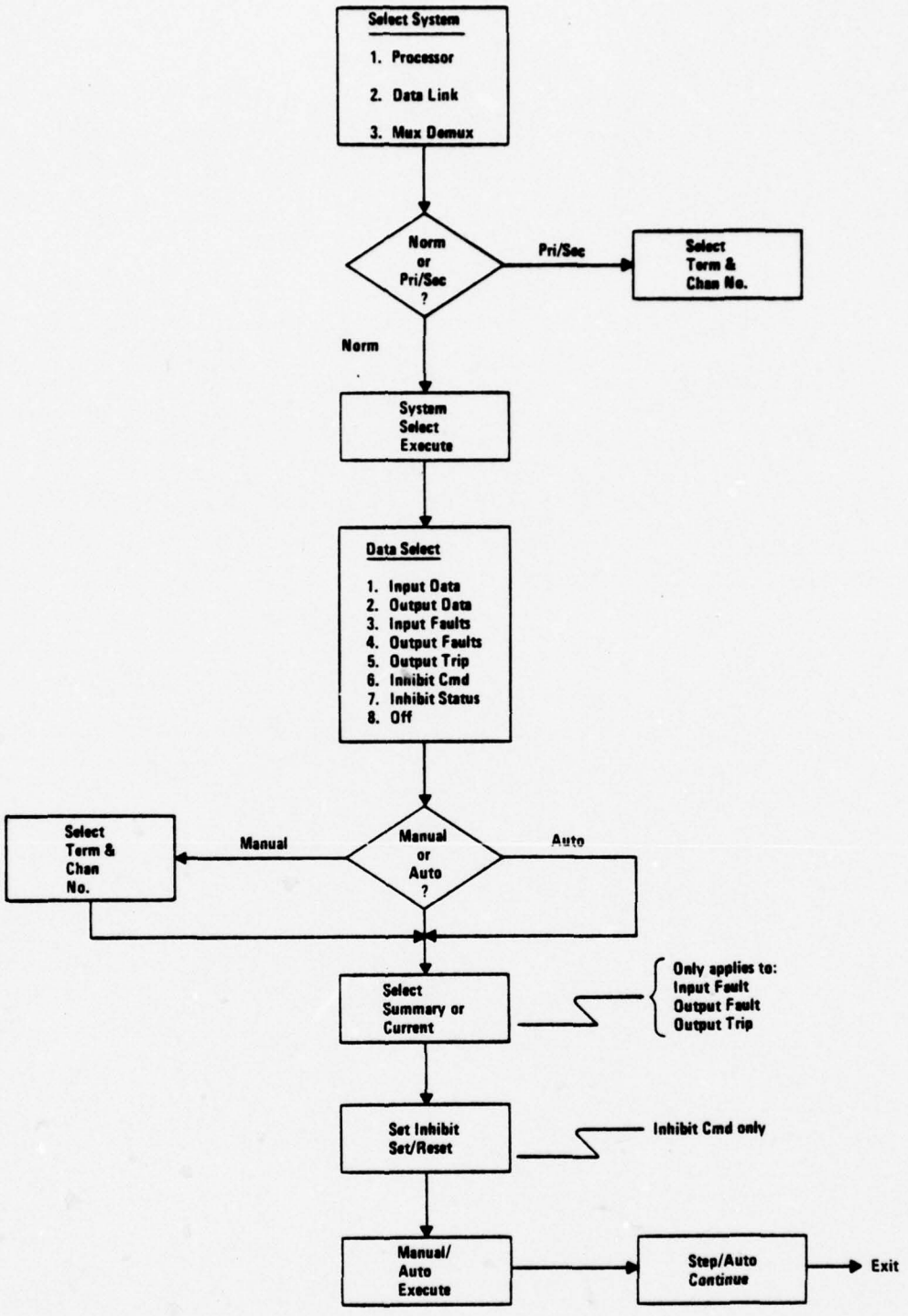


Figure 4-40. Control Panel Switch Logic

Program Memory Required

System Select	16 Bit Words	Micro-Ops	Time, usec
Move switch data word to Accumulator	2	8	1.36
Check Primary Processor Discrete	2	6	1.02
Check Secondary Processor Discrete	2	6	1.02
Check Pri Data Bus Discrete	2	6	1.02
Check Sec Data Bus Discrete	2	6	1.02
Check Pri MUX/DEMUX Discrete	2	6	1.02
Check Sec MUX/DEMUX Discrete	2	6	1.02
Three conditional Jumps	6	24	4.08
Move terminal and Channel Data word to Accum	2	8	1.36
Check term No if P/S MUX/DEMUX Set	2	6	1.02
Check sys select Execute Bit	2	6	1.02
Total	26		14.96

Data Select

Move Rotary Switch Data word to Accumulator	2	8	1.36
Shift data a maximum of eight times	8	48	8.16
Conditional Jump	2	8	1.36
Move switch data word to Accum	2	8	1.36
Check manual/auto and enter Bits	2	6	1.02
JMP to check terminal No. and channel No.	2	8	1.36
Move term/chan No. Data word to Accum	2	8	1.36
Check term No. & chan if manual	2	8	1.36
Move switch data to Accum	2	8	1.36
Check summary or current Bit	2	6	1.02
Check Inhibit Set/Reset Bit	2	6	1.02
Check Manual/Auto Execute Bit	2	6	1.02
Check Step/Auto continue Bit	2	6	1.02
	32		22.78

58 words of program memory required.

Subroutine Execution Time

37.74 usec per frame

Operational Duty Cycle

10 msec

Total Processor Time Required

3774 usec/sec

I/O Time

(None)

4.2.3.1.12 Format Alphanumeric Display Data

An alphnumeric display format is necessary to identify fault, trip, input and output data to the crew. Use of coded display data is undersirable for the F-14 considering the large number of signal sources and power controllers required for the aircraft. Based on a system containing 402 signal type outputs, 416 power controllers, 584 transducers and 60 MUX/DEMUX signals, an English language display of data is mandatory.

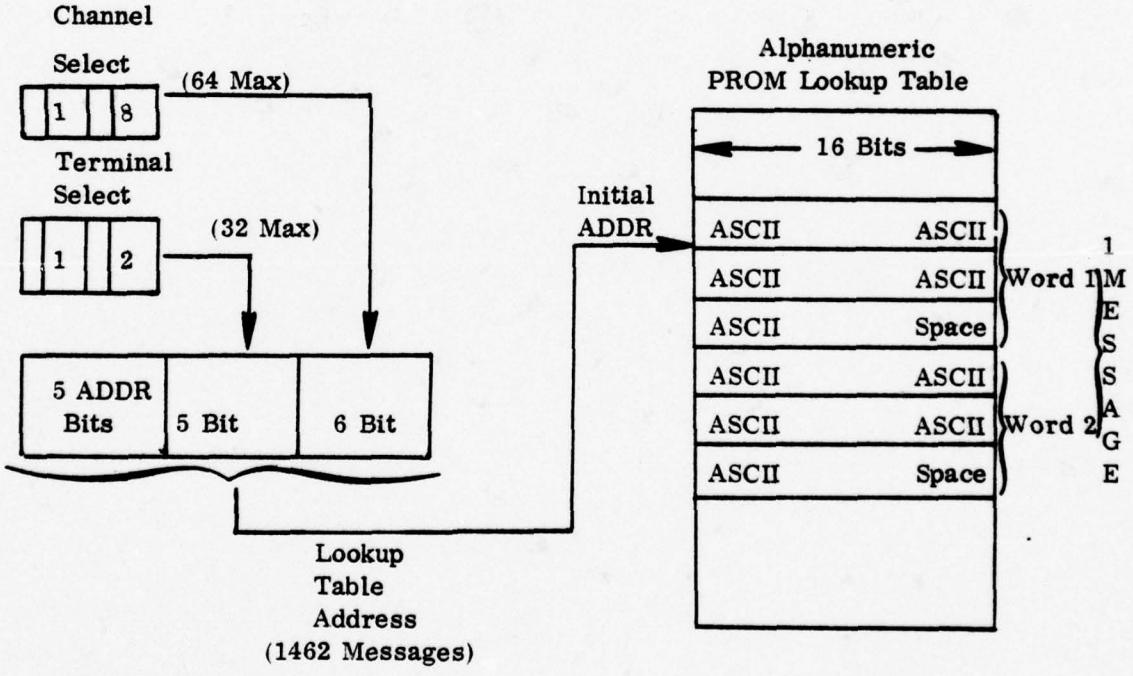
A look up table with 1462 messages would be loaded into permanent program memory. Each message consists of a five character display words. Characters are coded by means of a 6-bit ASCII code with two characters stored in each 16-bit memory word. A total of six memory words are, therefore, required for each two-word display message. Adressing of the look up table is accomplished by means of an 11-bit code (five bits from the terminal select thumbwheel and six bits from the channel select thumbwheel). Memory capacity for the look up table is six memory locations for each of 1462 messages, or 8772 16-bit words.

No attempt has been made at this time to reduce the size of the look up table memory requirements based on common usage of display words. A potential reduction of 24% may be possible based on the study results of SOSTEL requirements for AIMIS.

Interface prepared under NADC contract N62269-74-C0265. Figure 4-41 illustrates the display data message sequence and display format utilized.

Signal Requirements for Alphanumeric Lookup Table

Function	Type	No.
(1) DEMUX Power Controllers	Nominal	368
	Redundant	48
(2) Signal Type Outputs	GPMS	402
(3) MUX/DEMUX	No. 1 Control/ Display Panel	36
	No. 2 PGS Monitor/ Load Mgmt	24
(4) Transducer Inputs		584
	TOTAL	1,462



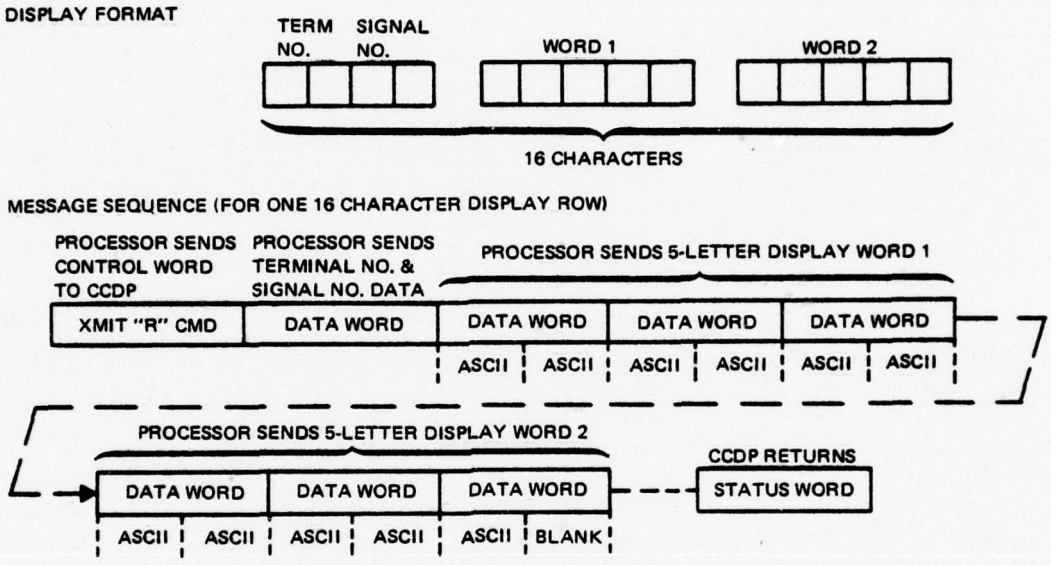


Figure 4-41. Display Data Message Sequence & Display Format

RAM Required

(None)

Program Memory Required

Fixed memory locations are basically required for ASCII lookup table of display words. Six memory locations (16 Bit) for each of 1462 messages.

Lookup Table Memory = 8772 Words

Control = 15 Words

Subroutine Execution Time

The control routine involves inputting an 11-bit address from the control panel. These 11-bit plus five fixed bits form the starting address of the data in the lookup table to be displayed. Six 16-bit lookup table words are transferred to RAM for subsequent transmission to the display panel.

		16 Bit Word	Micro-Ops	Time, usec	
	Input 11 address bits	2	8	1.36	Fix
	Add 6 Fixed Bits	1	6	1.02	Fix
	Move to Address Reg	1	5	0.85	Fix
(6)	Move M into RAM	4	15	2.55	
	Increment M	2	7	1.19	
	Compare End of M	1	7	1.19	
	Test JMP	2	6	1.02	
	Jumpout	2	8	1.36	Fix
		15			

Fixed Part = 4.59 usec

Iterative Part = 35.70 usec

40.29 usec/display request

Operational Duty Cycle

Duty cycle is a function of operator request frequency via the control/display panel which probably occurs no sooner than every five seconds.

I/O Time

(None)

4.2.3.1.13 Output A/N Data To Displays

This routine searches out display data requested by the control panel and loads it into the display output file. Requested display data may take the following forms:

- Discrete display of system faults and selection status of primary or secondary system elements.
- Two digit terminal number in seven segment format.
- 64 discrete display matrix of specific data associated with one terminal. These data may represent the following information.
  - MUX inputs or faults
  - DEMUX outputs, trips or faults
  - PGS MUX/DEMUX inputs, outputs, faults, trips
  - Summary file of trips or faults
  - Inhibit file
  - Individual alphanumeric descriptors

A control panel request for display results in the processor acquiring the requested data from the proper file, loading it into the display file, and formating the control word and its discrete bits for transmission to the display panel. Typical display word formats are illustrated in Fig. 4-42. Figure 4-43 illustrates the display flow diagram for output data to displays.

If alphanumeric display readouts are used on CCDP (to avoid the need for a code book) then additional data words are needed for the processor to communicate with the CCDP.

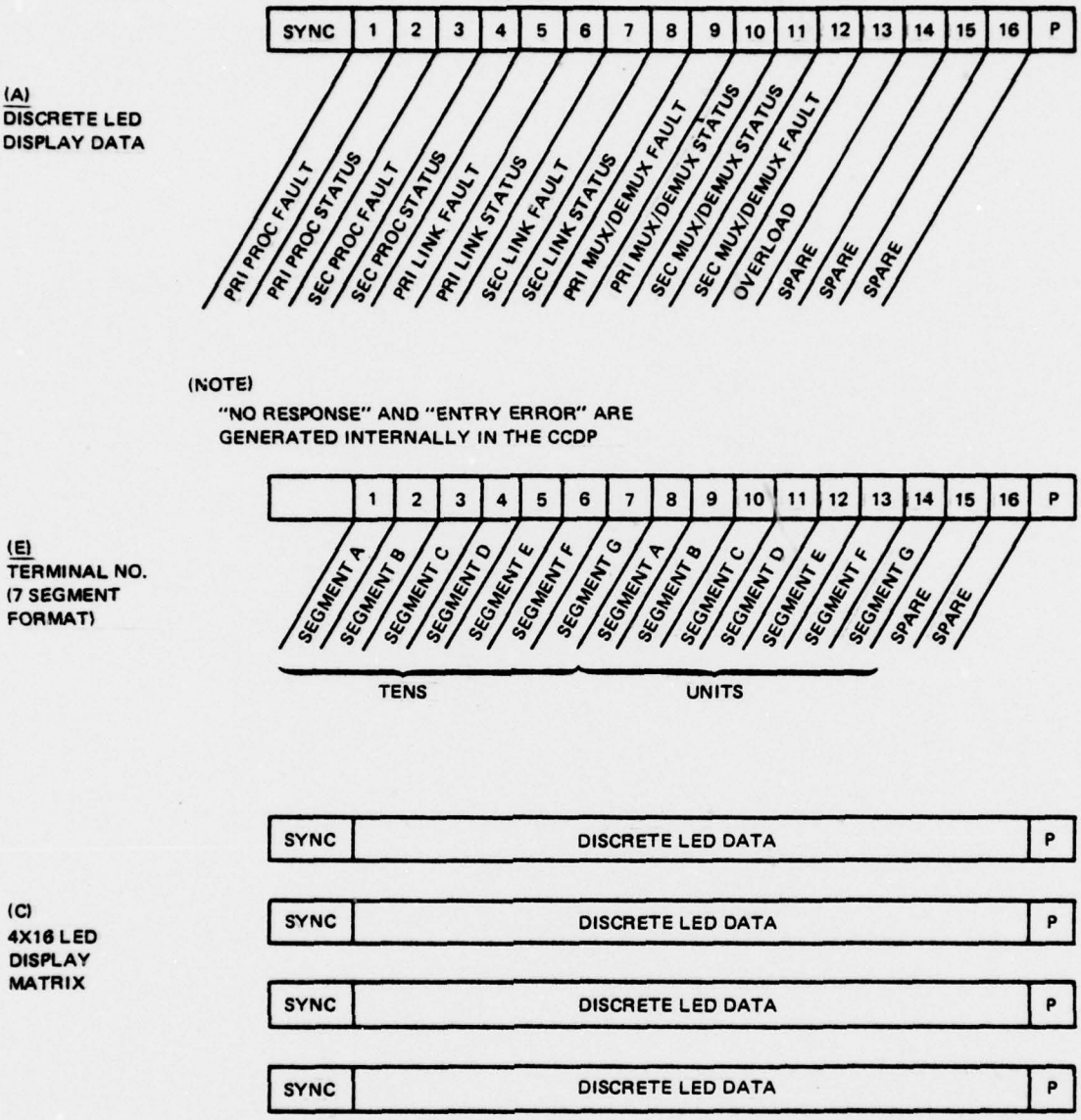


Figure 4-42. Crew Control Display Panel Data Word Format

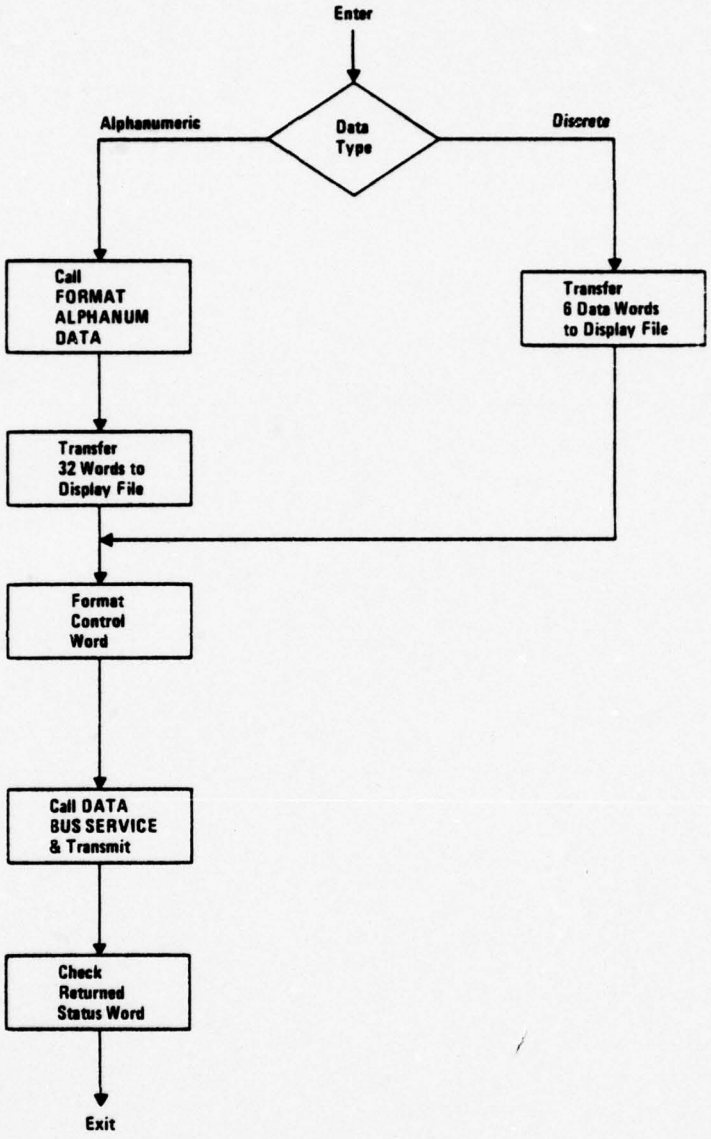
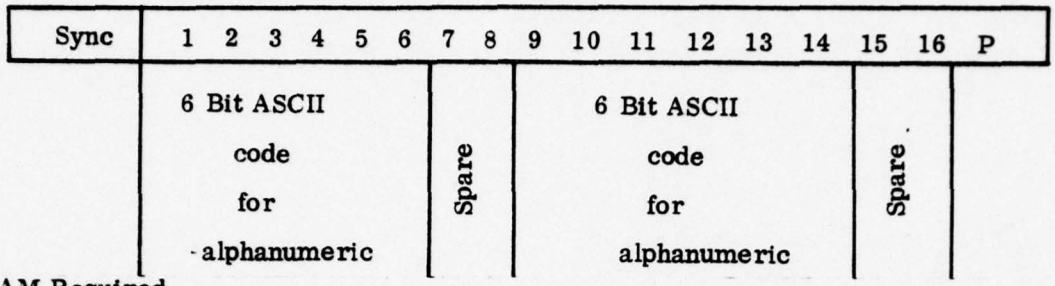


Figure 4-43. Output Data to Displays

Each data word would contain a six-Bit ASCII code for two alphanumeric displays for a complete display update, 32 data words of RAM are required in addition to the two data words for updating discrete LED's and terminal number display.



RAM Required

6 x 16 Bit words are required without using alphanumerics.

34 x 16 Bit words are required when alphanumerics are used.

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec	
Alphanumeric Discrete Jump	2	8	1.36	Fix
Call "Format Alphanumeric"	2	6	1.02	Fix
Store Initial Address	2	8	1.36	Fix
Move Data to Display File	2	8	1.36	
Increment Memory Addr	2	7	1.19	
Compare End of Addr	1	7	1.19	
Test Jump	2	6	1.02	
Fetch MUX Terminal Addr	2	8	1.36	Fix
Load Addr to Control Word	2	8	1.36	Fix
Set six Control Bits (six Fetch Bit)	12	72	12.24	Fix
Call "Data Bus Service"	2	6	1.02	Fix
Check Returned Status Word	16	96	16.32	Fix
	47			

47 fixed program words required.

Subroutine Execution Time

Fixed Part	=	36.04 usec
Iterative Part		
64 x 4.76	=	304.64 usec
		340.68 usec

340.68 usec/frame

Operational Duty Cycle

Duty cycle is a function of operator's inputs via the control/display panel. This probably occurs no more than every five seconds.

I/O Time

Transmit control word to display MUX/DEMUX	=	20 usec
Transmit 32 data words	=	640 usec
Receive status word	=	20 usec
Total I/O = 136 usec/sec		680 usec/frame

4.2.3.1.14 Update Summary Data File

This subroutine updates the summary data file containing faults and trips associated with MUX and DEMUX terminals. Simply put, the summary file data and newly received data are logically "OR'd" with the result used as the updated summary file word.

RAM Required

Summary data file is 164 x 16 Bit words

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Set up Initial Summary File Address	2	8	1.36 Fix
Set up Initial new Data Addr	2	8	1.36 Fix

	16 Bit Words	Micro-Ops	Time, usec	
Move File Word to Register "A"	2	8	1.36	
Move New Word to Register "B"	2	8	1.36	
OR B with A	1	5	0.85	
Move result to Sum. Addr	2	8	1.36	
Increment Sum. Addr	2	7	1.19	
Increment New Data Addr	2	7	1.19	
Test for Last Addr	1	7	1.19	
Test Jump	2	6	1.02	
Jump Out	2	8	1.36	Fix
	20			

20 words of fixed program words.

Subroutine Execution Time

Fixed Part	=	4.08 usec
Iterative Part 164 x 9.52	=	1561.28 usec
		1565.36 usec/update

Operational Duty Cycle

The duty cycle of reporting fault or trip data has been previously assumed as one SOSTEL terminal reporting trip or fault data during a one second period.

TOTAL Processor Time Required

1565.36 usec/sec

I/O Time

(None)

4.2.3.1.15 Update Inhibit File

Based on control panel inhibit commands, a file of 60 locations is set or cleared to control the inhibit status of the DEMUX power controllers. Figure 4-44 illustrates the flow diagram for maintaining the inhibit file.

RAM Required

60 x 16 Bit words of RAM

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Test Inhibit CMD Bit form Inhibit File Address	2	8	1.36
Move Terminal No.	2	8	1.36
Move Channel No.	2	8	1.36
Move Inhibit word from file	2	8	1.36
Test Inhibit set or clear bit	2	8	1.36
Form mask from chan No.	4	16	2.72
"OR/AND" mask with inhibit word	2	6	1.02
Move result to inhibit file	2	8	1.36
Jump out	2	8	1.36
	20		13.26

20 words of fixed memory required.

Subroutine Execution Time

13.26 usec/Inhibit Command

Operational Duty Cycle

1 inhibit command every 10 sec

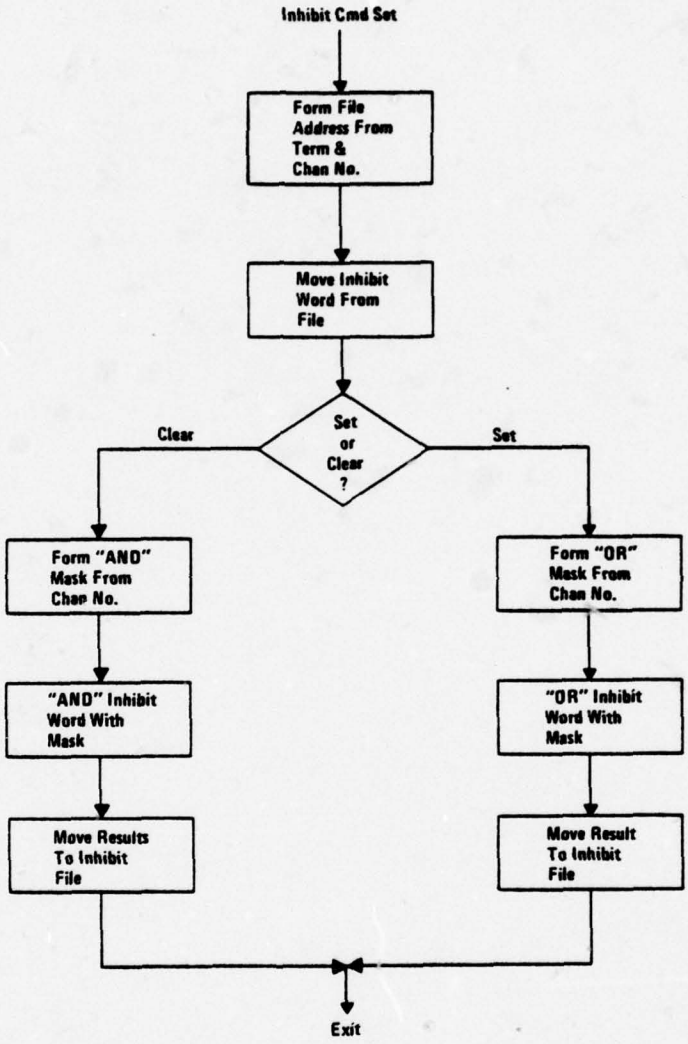


Figure 4-44. Maintain Inhibit File

Total Processor Time

1.33 usec/sec

I/O Time

(None)

4.2.3.1.16 Data Link Status Determination

This routine determines the operational health of the active and standby data links. Whenever a multiplex terminal is addressed and the terminal does not respond with a status word, the data link and terminal are suspect. This routine isolates the problem to either the data link (primary or secondary), the terminal (primary or secondary redundant elements) or complete terminal failure.

The approach taken to isolate the problem is to repeat the message on the alternate data link. If the terminal still doesn't respond, the terminal is commanded to receive and transmit on its alternate redundant elements. A further check of the data link involves transmitting to an alternate terminal to isolate the problem to the data link or the originally addressed terminal. Figure 4-45 illustrates the data link status determination flow

RAM Required

(None)

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Response Received (JMP)	2	6	1.02
Repeat Message (Bus Service)	(Included)	-	14.00
Response Received (JMP)	2	6	1.02
Redundant Element Cmd (Bus Service)	-	-	14.00
Repeat Message (Bus Service)	-	-	14.00

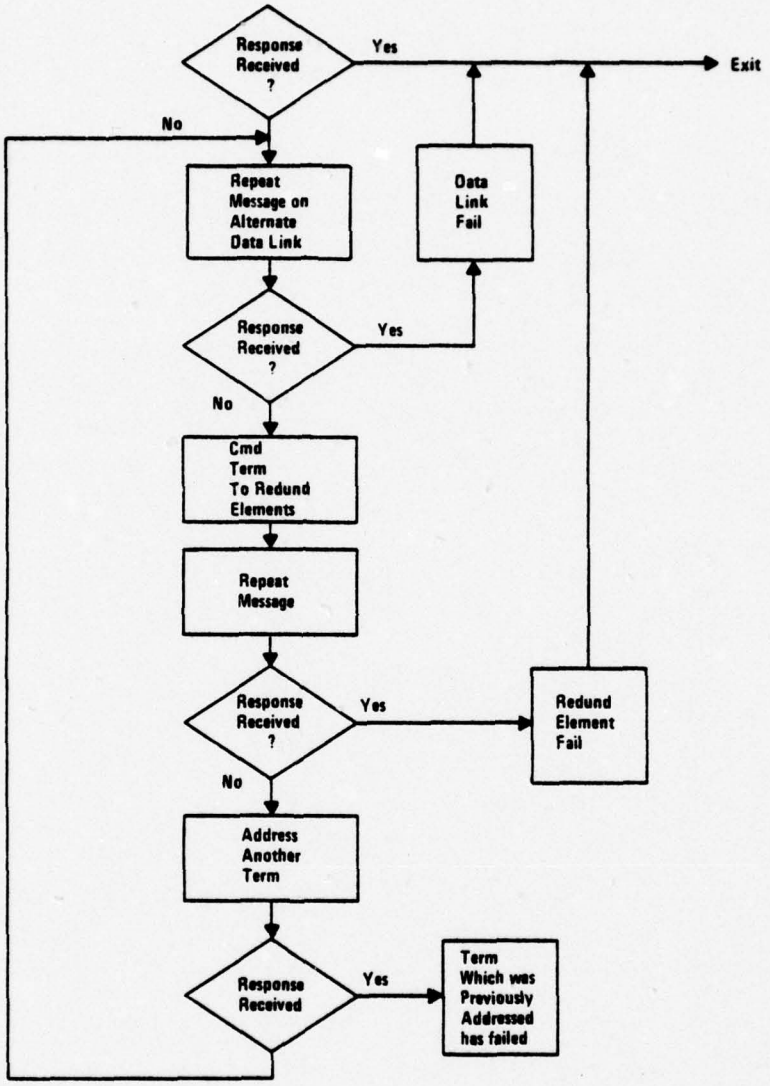


Figure 4-45. Data Link Status Determination

	16 Bit Words	Micro-Ops	Time, usec
Response Received (JMP)	2	6	1.02
Address new Terminal (Bus Service)	-	-	14.00
Response Received (JMP)	2	6	1.02
Set Term Fail. Flag (MVAM)	2	7	1.19
	10		61.27 usec

10 fixed program words required.

Subroutine Execution Time

61.27 usec

Operational Duty Cycle

Usage depends on frequency of failure of either redundant dual data bus or SOSTEL line driver/receivers. Considering AAES reliability requirements, the predicted usage of this subroutine during a flight is negligable.

Total Processor Time Required

(None)

I/O Time

A maximum of four transmission (20 bits each) and three receptions (20 bits) are required to check out a faulty line and/or terminal. The I/O requirement is 140 usec when the routine is used.

4.2.3.1.17 Processor Follow-Up Mode

During operation of the SOSTEL system, one of the redundant processors is active while the other processor must be ready to take over control and operation of the system if commanded to do so. This requires that the processor is up to date regarding the current status of the system. Without this capability, data stored in one processor would be lost to the other upon transfer of control.

The approach taken here is to have the inactive processor in a followup mode where it would receive all data addressed to the processors, but would not transmit until it became active. Implementation of this function can be accomplished in the data terminal hardware of the terminals associated with the processors. Alternatively the function may also be performed by the processor itself by inhibiting transmission of data onto the bus. This latter solution is preferred since it results in commonality of data terminal hardware designs. Only minimal software is required to set a "no transmit" flag.

4.2.3.1.18 Self-Test

Self-test software performs non-interfering tests of the processor and software by check sum evaluation of critical memory areas, evaluation of counters and indexes to verify in-bounds operation. Errors are identified by the processor system fault indicators on the control display panel.

RAM Required

(None)

Program Memory Required

128 x 16 Bit Word

Subroutine Execution Time

Time to execute check sums of fixed and RAM memory may be spread over seconds or minutes of processor time. This is due to the fact that the routine operates whenever there is free time available, and thus uses all unused processor time. Total time to perform memory check sum is estimated on the basis of moving each memory word and adding. The resultant sum is compared to a fixed check sum constant for program memory. For RAM memory the check sum constant is floated due to the variability of stored data. Any new data entered into RAM causes the check sum constant to be updated.

Fixed Program Memory Check Sum

Each word in Fixed Memory is moved to accumulator and added to the contents of a register. At the end of check sum, the register is compared to the constant.

	Micro-Ops	Time, usec
Move MEM to Accumulator	8	1.36
Add Accum to Register	6	1.02
		2.38 usec

2.38 usec/fixed memory word.

Fixed Memory Time	= 2.38 x 19,780	=	47,076 usec
RAM Memory Time	= 2.38 x 1,487	=	3,539 usec
			50,615 usec

4.2.3.1.19 System Test

System test capability should be incorporated into the SOSTEL design for ground checkout purposes. Following initialization and self-test of the processor, the processor would enter the system test mode. In this mode, data would be requested from all MUX transducers looking for faults (input data would not be processed by the Boolean equations during system test). Input faults would be displayed to alert the operator.

To check DEMUX terminals, all power controllers would be inhibited to prevent activation during DEMUX tests. Each terminal is interrogated, in turn, looking for DEMUX fault data which is displayed on the control panel. Figure 4-46 illustrates the flow diagram for system test.

RAM Required

(None)

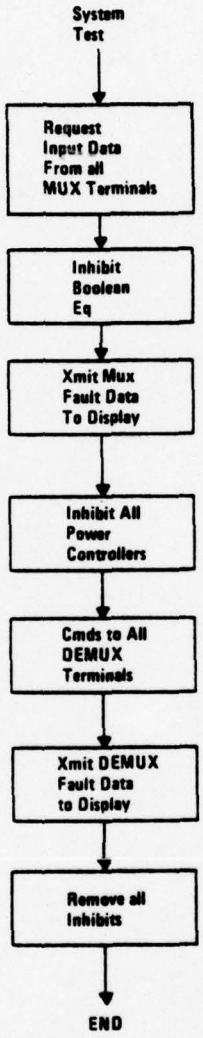


Figure 4-46. System Test Flow

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Inhibit Boolean Routine	2	8	1.36
Request MUX Data	(Already Included)	-	341.36
Transmit Faults to Display		-	I/O Time
Inhibit all Pwr Controllers		-	308.38
Cmds to all DEMUX's		-	545.36
Transmit faults to display		-	I/O Time
Remove all Inhibits		-	308.38
CHANGE INHIBIT FILE			
Set initial Inhibit file Address	2	8	1.36 Fix
Move all one's to Memory	2	8	1.36
Increment Mem Addr	2	7	1.19
Test end addr	1	7	1.19
Test Jump	2	8	1.36
Jumpout	2	6	1.02 Fix
	11		

Fixed Part = 2.38 usec

Iterative Part 60 x 5.1 = 306.00 usec

308.38 usec

Transmit Faults to Display

The Fixed program exists as part of the main program, therefore, no additional program memory is required. Time to transmit faults to the display is based on one fault per terminal. Therefore all terminal discrete fault data must be sent to the display. This is essentially I/O time.

Program memory required: 24 x 16 Bit words.

Subroutine Execution Time

1504.84 usec/system test

Operational Duty Cycle

System test done on the ground prior to flight.

Total Processor Time Required - not included, in operational processor time.

I/O Time	Time, usec
Request MUX data	341.36
CMDS to DEMUX	545.36
Transmit Faults to Display	
MUX (6 x 10 x 20 usec)	1200
DEMUX (6 x 14 x 20 usec)	1680
System Test I/O Time	3766.72 usec

4.2.5.1.20 System Status and Faults

Once per frame, information is transmitted to the control/display panel to update discrete indicators as to system status, system faults, and processor overload.

RAM Required

One word required for discrete storage.

Program Memory Required

	Words	Micro-Ops	Time, usec
Move RAM Word to Transmit File	2	8	1.36
Call output Data to Display	2	6	1.02
	4		2.38 usec

Four words of Fixed Memory

Subroutine Execution Time

2.38 usec per frame

Operational Duty Cycle

Every 10 msec

Total Processor Time

238 usec/sec

I/O Time

60 usec/frame

6000 usec/sec

4.2.3.1.21 Inhibit Faulted Inputs

If a transducer input is faulted, then the Boolean equation terms using that input will be inhibited. The last value of the input prior to the fault will be held. Whenever four input data words are received from a MUX terminal, the fault flag associated with the four words is checked. If no faults are present, the appropriate IRAM locations are updated. If the fault flag for a particular MUX is set, bits of the BIRAM location corresponding to the MUX fault words are examined. Only those bits without BIRAM fault bits set are updated in IRAM. Figure 4-47 illustrates flow diagram for inhibiting troubled inputs.

RAM Required

One bit per MUX is required for fault flags; 10 MUX terminals require 10 bits (one 16 bit word required).

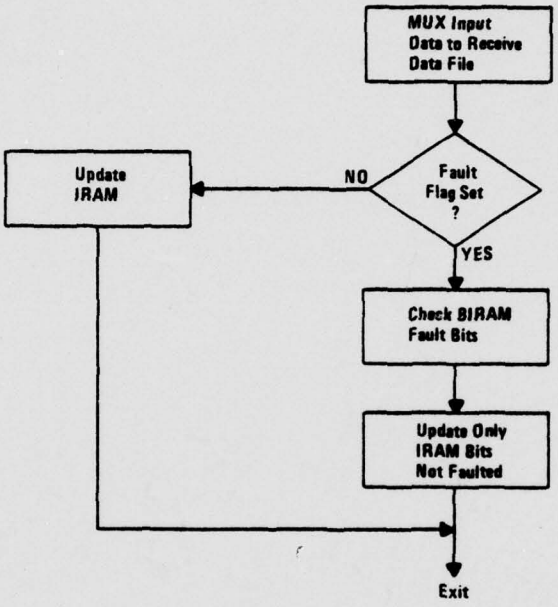


Figure 4-47. Inhibit Faulted Input Flow

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec
Check Fault			
Set Memory Address	2	8	1.36
Move Word to Accumulator	2	8	1.36
Shift	1	6	1.02
Test Bit	1	7	1.19
Jump	2	8	1.36
Check BIRAM Fault Bits	4	24	4.08
Jump	2	8	1.36
	14		11.73

14 fixed program words required.

Subroutine Execution Time

11.73 usec/MUX terminal

Execution Time = 117.3 usec/frame

Operational Duty Cycle

10 msec

Total Processor Time Required

11,730 usec/sec

I/O Time

None

4.2.3.1.22 Check Inhibit File

This subroutine is called after Boolean processing is completed. Its purpose is to check the output inhibit file to assure that output channels which are manually inhibited are not updated on the basis of new Boolean solutions.

RAM Required

(None)

Program Memory Required

Each DEMUX output word, resulting from the solution of Boolean equations is passed through the "check inhibit file" routine before being output to the DEMUX terminals. The data which is finally output is the resultant of the following equations.

$$OUT = BS \cdot \overline{IF} = BS \cdot IF \oplus FFFF$$

where:

OUT = DEMUX output data

BS = Boolean solution word

IF = Output Inhibit File

FFFF = 16 Bit Hexidecimal One's

For each Boolean solution word, a corresponding word for that DEMUX terminal is contained in the Inhibit File. By "anding" the Boolean solution with the complement of the inhibit file word, the output inhibit function is mechanized.

	16 Bit Words	Micro-Ops	Time, usec
Address Boolean Solution Word	2	10	1.7
Address Inhibit File Word	2	10	1.7
Move Boolean Sol word to REG	2	8	1.36
Move IF word to Accum	2	8	1.36
ONES Complement Accum	1	4	0.72
AND REG with Accum	1	5	0.85
Move Accum to Output File	1	10	1.70
Inclement Addr Register	1	4	0.72
Jump	2	8	1.36
	14		

14 fixed program words.

Soubroutine Execution Time

Fixed Part	=	4.76 usec
Iterative Part (60 x 6.71)	=	402.60 usec
		407.36 usec/frame

Operational Duty Cycle

10 msec

Total Processor Time Required

40,736 usec/sec

I/O Time

(None)

4.2.3.1.23 Output Discrete Data to Display

This subroutine is used to output all display panel data other than alphanumeric type data. This amounts to outputting six data words to the display.

RAM Required

6 x 16 bit words of RAM

Program Memory Required

	16 Bit Words	Micro-Ops	Time, usec	
Store initial Address	2	8	1.36	Fix
Move data to Display File	2	8	1.36	
Increment Memory Addr	2	7	1.19	
Compare End of Addr	1	7	1.19	
Test Jump	2	6	1.02	
Fetch MUX Term Addr	2	8	1.36	Fix
Load Addr to Control Word	2	8	1.36	Fix

	16 Bit Words	Micro-Ops	Time, usec
Set 6 Control Bits	12	72	12.24 Fix
Call Data Bus Service	2	6	1.02 Fix
Check returned Status Word	16	96	16.32 Fix
	43		

43 program words required.

Subroutine Execution Time

Fixed Part	=	33.66 usec
Iterative Part (60 x 4.76)	=	28.56 usec
		62.22 usec

62.22 usec/frame

Update Rate

Five sec

I/O Time

Output Control Words	20 usec
Output 6 Display Words	120 usec
Receive Status Word	20 usec
I/O Time/Frame	160 usec

4.2.4 SOSTEL CREW CONTROL AND DISPLAY

The SOSTEL crew control display panel (CCDP) requirements and specifications were examined for the F-14A AAES application. Comments on the specification and recommended improvements based on ease of operating the CCDP were developed.

Basically, the CCDP is a maintenance panel for laboratory use; it is not part of the flight hardware. Therefore, there is a requirement to provide data and override control for the flight crew. This can be satisfied by the master monitor display (MMD), which is part of AIMIS, and a keyboard which interacts with the MMD. Since an MMD will not be available during the lab development and flight test phase of the AAES, an interim pilots display unit should be incorporated in the SOSTEL control group. The operation of a interactive alphanumeric panel and a pilots panel which could serve this function are described. Three typical CCDP panel layouts are included and discussed. One panel configuration represents that defined by the SOSTEL specification. The second panel includes an alphanumeric display, while maintaining the SOSTEL specified controls arrangement. The final panel represents an interactive control/display panel with alphanumeric displays and pushbutton controls.

Other aspects of the CCDP examined include the type of data terminal which should be used for controls and displays and I/O arrangements. Interactive control/display functions are identified together with typical display formats. Flow diagrams of the logic for interactive operation are included.

4.2.4.1 Comments on SOSTEL Specification CCDP Requirements

The crew control display panel arrangement as described in the SOSTEL specification is intended for laboratory use. Strong emphasis has been placed on the panel use for maintenance purposes and other post-flight activities. The number of switches, controls, indicators and discrete LED displays identified would be undesirable for an operational SOSTEL flight control panel. Operationally, it is desirable to reduce the switch operating burden on the operator, while still maintaining all the functions necessary for maintenance action.

CCDP requirements and panel configuration as applied to the F-14A AAES necessitates display of a large quantity of data. Interpreting or identifying some 1400 data items would require continual use of a code book organized by terminal and channel number. Each of the 64 terminal bits would have to be identified as to its function. This approach may be acceptable for ground maintenance purposes, but it would be very inefficient for flight crew operations. An alphanumeric display is recommended to facilitate the use of the CCDP during maintenance operations.

"Overload" conditions of the processor as indicated on the panel is based on the length of real time necessary to complete one pass through the processor self-test routine. "No Response" is similarly processor determined whenever a MUX or DEMUX is addressed, but does not respond. A software routine "Data Link Status Determination" isolates the reason for no return data to either the data link or the data terminal. The "No Response" indicator on the panel however is activated by the initial lack of return data from a data terminal.

When the processor communicates with an alphanumeric control panel (via the MUX/DEMUX), more than four 16-bit data words are required for a complete update of panel displays (64-bit display matrix, two six-bit ASCII words for terminal number and 14 bits for System Status and System Fault discrete displays). This could be accomplished by sending three message groups each having four data words or using more words in a single message. The 1553A STD permits up to 32 words per message, and the processor can be programed to provide message lengths compatible with each units requirements.

When an alphanumeric display approach is taken, one data word would contain the six-bit ASCII code for two alphanumeric characters. Thirty-two data words (one message) are required for a complete display panel update. If the transmission were restricted to groups of four data words, then an overhead of eight control words and eight status words would be incurred for each complete display update.

All of the foregoing considerations can be rectified by appropriate system design techniques. The need for a code book to identify terminal channel functions is

eliminated through the use of alphanumeric displays. Panel control switch functions can be reduced through the use of an interactive display. Overhead in terms of control and status words associated with four data word message groups is eliminated by using a 1553A, 32-word message structure in bus communications to the CCDP.

4.2.4.2 Control Display Requirements and Functions

Control and display panel requirements for the CCDP are as specified in the SOSTEL specification. All functions of the F-14 AAES/SOSTEL design can be satisfied by the CCDP with minor exceptions. Table 4-41 summarizes all CCDP controls and displays. One additional function included is associated with PGS monitoring. A discrete display indicator has been added to alert the operator that one of the PGS functions being monitored has exceeded its range of acceptable limits. By including an additional position on the rotary switch for "PGS MON", the operator may elect to call up PGS monitor display data. This determines which PGS function has exceeded its limits.

When alphanumeric displays are employed on the CCDP panel, the function of the channel selection switch should be modified. The channel selector set at 00 would indicate the display of discrete data (binary) for the terminal selected. Any other channel number indicated on by the channel select thumbwheel means that the information associated with that channel is displayed in alphanumeric format.

Figure 4-48 shows the interrelationships between CCDP panel switches. For example, the SYSTEM SELECT EXECUTE switch is used in conjunction with PROCESSOR SELECT, DATA LINK SELECT, MUX/DEMUX SELECT, TERMINAL SELECT & CHANNEL SELECT switches. Another example is the STEP/AUTO CONTINUE switch whose function of step or auto continue is determined by the MANUAL/AUTO switch.

4.2.4.3 Typical CCDP Panel Layouts

Three different crew control/display panel (CCDP) configurations are discussed. These typical panel layouts for SOSTEL include the following:

Table 4-41. SOSTEL CONTROL AND DISPLAY PANEL FUNCTIONS (Sheet 1 of 3)

Control Functions	
Switch	Function
ROTARY SWITCH (9 Position)	Requests different types of data to be displayed from the terminal identified by the 2-digit thumbwheel, and channel identified by 2-digit thumbwheel - "OFF" Position sets panel to flight mode - "INPUT DATA" Requests current input data - "OUTPUT DATA" Requests current output data - "INPUT FAULTS" Requests both summary & current Input Faults from MUX terminal - "OUTPUT FAULTS" Requests both summary & current Output faults from DEMUX terminal Trips from DEMUX terminal - "INHIBIT CMD" Activates inhibit set/reset switch - "INHIBIT STATUS" Requests current output inhibit data of DEMUX terminals - "POWER GEN SYSTEM" Displays PGS monitor faults
SUMMARY/CURRENT DATA SWITCH (2 Position)	Operates in conjunction with rotary switch and indicates whether current or summary data should be displayed
INHIBIT SET/RESET SWITCH (2 Position)	Operates only when rotary switch is in "INHIBIT CMD" position. It indicates whether the terminal channel should set or reset.
STEP/AUTO CONTINUE SWITCH (Momentary)	Step to next terminal in manual mode or continue to scan terminals in automatic mode
MANUAL/AUTO EXECUTE SWITCH (Momentary)	Enters functions specified by rotary and manual/ automatic switches
MANUAL/AUTOMATIC SWITCH (2 Position)	In auto mode processor searches for faults, trips, and inhibits, specified by rotary switch. In manual mode, only data from terminal identified by thumbwheel is displayed

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Table 4-41. SOSTEL CONTROL AND DISPLAY PANEL FUNCTIONS (Sheet 2 of 3)

Control Functions	
Switch	Function
SYSTEM SELECT EXECUTE (Momentary)	Enters selections made on system select and thumbwheel select switches
SUMMARY RESET (Momentary)	Clears processor memory containing summary of input/output faults and trip data
PC TRIP RESET (Momentary)	Instructs processor to reset all power controllers
PROCESSOR SELECT (3 Position)	Selects redundant half of processor. "PRI/SEC" is manually selected, while in "NORM" processor selects
DATA LINK SELECT (3 Position)	Selects redundant half of data link. "PRI/SEC" is manually selected, while in "NORM" processor selects
MUX/DEMUX SELECT (3 Position)	Selects redundant half of MUX/DEMUX addressed on thumbwheel switch. "PRI/SEC" is manually selected while processor selects in "NORM" position
TERMINAL SELECT (2 Digit Thumbwheel)	Indicates terminal address for requested data or primary/secondary selection. 00 indicates all terminals are affected by the selected function
CHANNEL SELECT (2 Digit Thumbwheel)	Channel select at 00 indicates display of descrete data for terminal selected. Any other channel indicates alphanumeric display output (inhibit function is determined by rotary switch)

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Table 4-41. SOSTEL CONTROL AND DISPLAY PANEL FUNCTIONS (Sheet 3 of 3)

Display Functions	
Display	Function
ENTRY ERROR (Discrete)	Indicates illegal switch settings associated with following: SYSTEM SELECT EXECUTE, MANUAL/AUTO EXECUTE or STEP/AUTO CONTINUE
TERMINAL NUMBER (2 Digit)	Indicates terminal associated with data on 64 LED matrix & MUX/DEMUX status/fault LEDS
64 LED MATRIX	Indicates fault, trip & inhibit data of addressed table
SYSTEM STATUS (6 Discretes)	Indicates which redundant half of processor, data link and MUX/DEMUX (being addressed) is in use - Primary processor in use - Secondary processor in use - Primary data link in use - Secondary data link in use - Primary MUX/DEMUX in use Terminal being - Secondary MUX/DEMUX in use addressed
SYSTEM FAULTS (8 Discretes)	Indicates which redundant half of processor, data link and MUX/DEMUX (being addressed) is at fault Also data handling faults - Fault in primary processor - Fault in secondary processor - Fault in primary data link - Fault in secondary data link - Fault in primary MUX/DEMUX - Fault in secondary MUX/DEMUX - System overload - Processor not responding
PGS	- Indicates a PGS monitor situation exists

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		SUMMARY/CURRENT	INHIBIT SET/RESET SW	STEP/AUTO CONTINUE SW	MANUAL/AUTO EXECUTE SW	SYSTEM SELECT EXECUTE	SUMMARY RESET	PC RESET	MANUAL/AUTO SW	TERMINAL SELECT SW	CHANNEL SELECT SW
ROTARY SW	OFF				X						
	INPUT DATA				X				X	X	X
	OUTPUT DATA				X				X	X	X
	INPUT FAULTS	X			X				X	X	X
	OUTPUT FAULTS	X			X				X	X	X
	OUTPUT TRIP	X			X				X	X	X
	INHIBIT CMD		X		X				X	X	X
	INHIBIT STATUS				X				X	X	X
	PGS MONIT.	X									
MANUAL/AUTO SW				X	X						
PROCESSOR SELECT						X					
DATA LINK SELECT						X					
MUX/DEMUX SELECT						X					
TERMINAL SELECT						X					
CHANNEL SELECT						X					

Figure 4-48. Crew Control Panel Switch Relationships

- SOSTEL Specification system per Control Group, Electric Power OK-171, specification sheet No. NADC-VT-TS-7301/1A
- Alphanumeric display with SOSTEL specified controls and switches
- Alphanumeric display with pushbutton controls.

4.2.4.3.1 SOSTEL Specification CCDP

Figure 4-49 is the CCDP from the SOSTEL specification. Figure 4-50a, b, c, are the associated CCDP data bus word formats. Its layout is intended for mounting in a standard 19-in. rack that is suitable only for laboratory installation, integration, and checkout because of the following:

- The shear quantity of display data necessary to monitor an F-14 AAES/ SOSTEL system would be difficult to interpret by the operator or pilot using a discrete Fault/Trip/Inhibit/Data Display Matrix. With 1462 display messages necessary for the F-14, a code book would be necessary to identify and interpret displayed conditions on the discrete display matrix. For this reason, an alphanumeric display matrix has been investigated to reduce the work load and chance for error in interpreting data
- The large number of controls and switches shown in the SOSTEL specified CCDP could be reduced further by having the CCDP as an interactive panel.

4.2.4.3.2 Alphanumeric Display with Manual Controls

Figures 4-51 and 4-52 show typical panel arrangements with alphanumeric displays. In both cases the control switch functions are as specified in the SOSTEL specification. The basic difference is that a rotary select switch is used on one panel, while the other panel maximizes the use of pushbutton switches.

For an effective control panel, both the number of controls and interdependent switch actions should be reduced. The objective is to relieve the operator of much of the burden of operating the system through reduction of the number of operator actions required to control and callup display data. This could be accomplished by using the proposed interactive pilots display for the CCDP function.

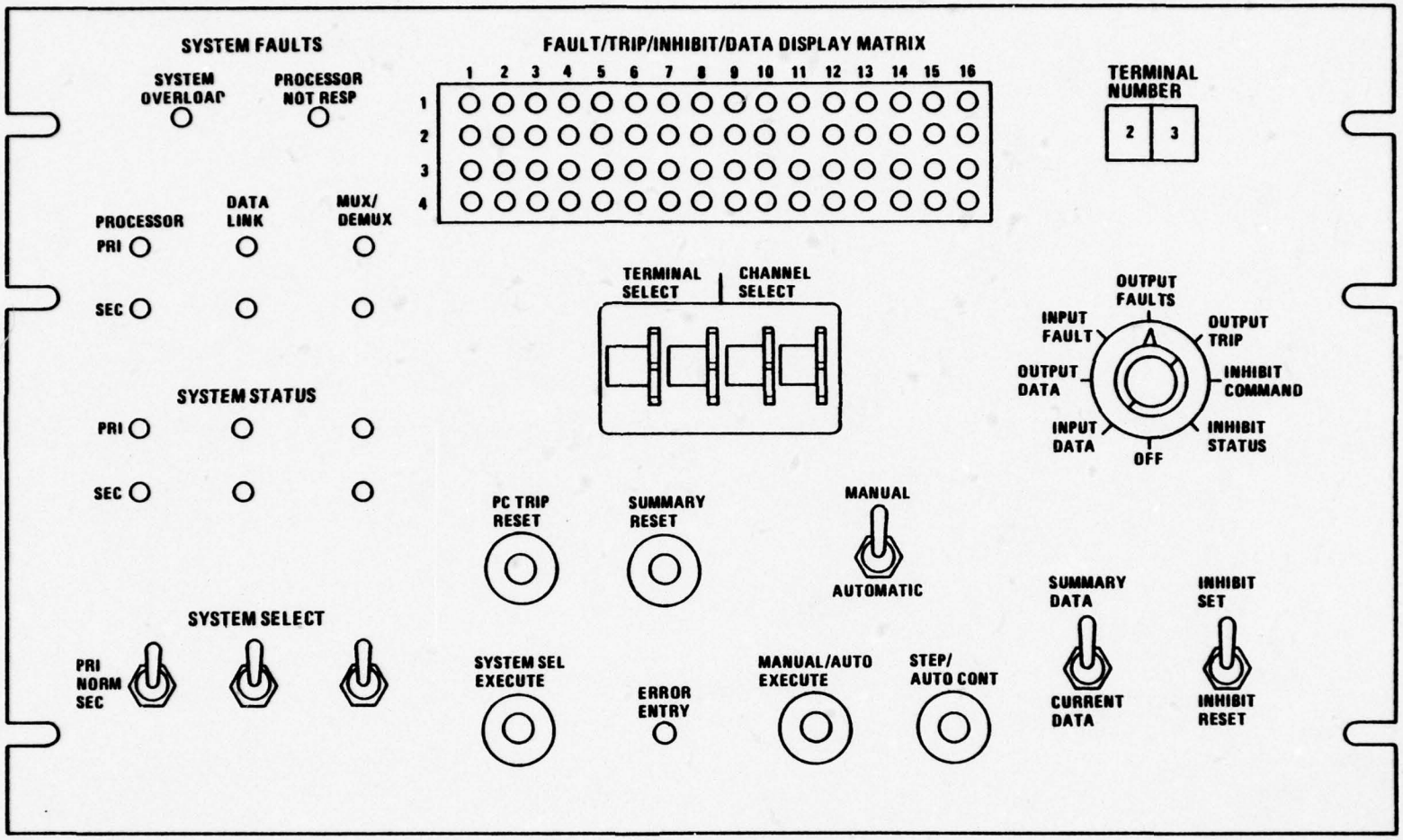


Figure 4-49. CCDP From SOSTEL Specification

	Control Word	Status Word	Data Word 1	Data Word 2
1	Sync	Sync	Sync	Sync
2	Pattern	Pattern	Pattern	Pattern
3				
4				
5	CDDP	Hardwired		
6	MUX	CCDP		
7	Address	MUX	Terminal	Channel
8		Address	Designation	Designation
9	T/R	Message Error		
10	Bus Select Pri (0), Sec (1)	Bus Select Pri (0), Sec (1)		
11	Unassigned	Unassigned	Update Indicator	Inhibit Reset (0) Inhibit Set (1)
12	Unassigned	Unassigned	Terminal Pri (0) Terminal Sec (1)	Override Off (0), On (1)
13	Unassigned	Parity Error	Terminal Select Normal (0), Force (1)	(MSB)
14	Unassigned	Unassigned	Processor Pri (0) Processor Sec (1)	Request
15	Unassigned	Unassigned	Processor Select Normal (0), Force (1)	Code
16	Unassigned	Unassigned	System Execute Command	(LSB)
17	Unassigned	Data Flag	Current Data (0) Summary Data (1)	Manual (0) Auto (1)
18	Unassigned	Unassigned	Summary Memory Reset Command	Step/Auto Continue Command
19	Unassigned	Terminal Flag	PC Trip Reset Command	Manual/Auto Execute Command
20	Parity	Parity	Parity	Parity

Figure 4-50A. CCDP Multiplexer Control, Status, and Data Word Formats (Sheet 1 of 2)

NOTES:

(1) Data words 3 and 4 are like data words 1 and 2 except bits 4-19 are all zeros.

(2) Request Codes are:

0 - Off

1 - Input Data

2 - Output Data

3 - Input Faults

4 - Output Faults

5 - Output Trips

6 - Terminal Fail

7 - Inhibit Command

8 - Inhibit Status

9 - Override Command

10 - Override Status

Figure 4-50A. CCDP Multiplexer Control, Status, and Data Word Formats (Sheet 2 of 2)

	Control Word	Data Word 1	Data Word 2-4	Status Word
1	Sync	Sync	Sync	Sync
2	Pattern	Pattern	Pattern	Pattern
3				
4		Clear Data Display		
5	CCDP	Unassigned		Hardwired
6	DEMUX	Unassigned		CCDP
7	Address			DEMUX
8				Address
9	T/R	Failed Terminal		Unassigned
10	Bus Select Pri (0), Sec (1)	Designation		Bus Select Pri (0), Sec (1)
11	Data Terminal		Unassigned	Unassigned
12	Address			Unassigned
13	CCDP DEMUX	Primary Link Failure		Parity Error
14	Designation	Secondary Link Failure		Unassigned
15		Unassigned		Unassigned
16		Processor Status Pri (0), Sec (1)		Unassigned
17	Terminal Status Pri (0), Sec (1)	Secondary Processor Fault		Unassigned
18	Secondary Terminal Fault	Primary Processor Fault		Unassigned
19	Primary Terminal Fault	System Overload		Terminal Flag
20	Parity	Parity	Parity	Parity

Figure 4-50B. CCDP Demultiplexer Control, Data, and Status Word Formats For System Status Output to CCDP

	Control Word	Data Word 1-4	Status Word
1	Sync	Sync	Sync
2	Pattern	Pattern	Pattern
3			
4			
5	CCDP		Hardwired
6	DEMUX		CCDP
7	Address		DEMUX
8			Address
9	T/R		Message Error
10	Bus Select Pri (0), Sec (1)	Requested	Bus Select Pri (0), Sec (1)
11		Data	Unassigned
12	Data		Unassigned
13	Terminal		Parity Error
14	Designation		Unassigned
15			Unassigned
16			Unassigned
17	Terminal Status Pri (0), Sec (1)		Unassigned
18	Secondary Terminal Fault		Unassigned
19	Primary Terminal Fault		Terminal Flag
20	Parity	Parity	Parity

Figure 4-50C. CCDP Demultiplexer Control, Data, and Status Word Formats For Data Output to CCDP

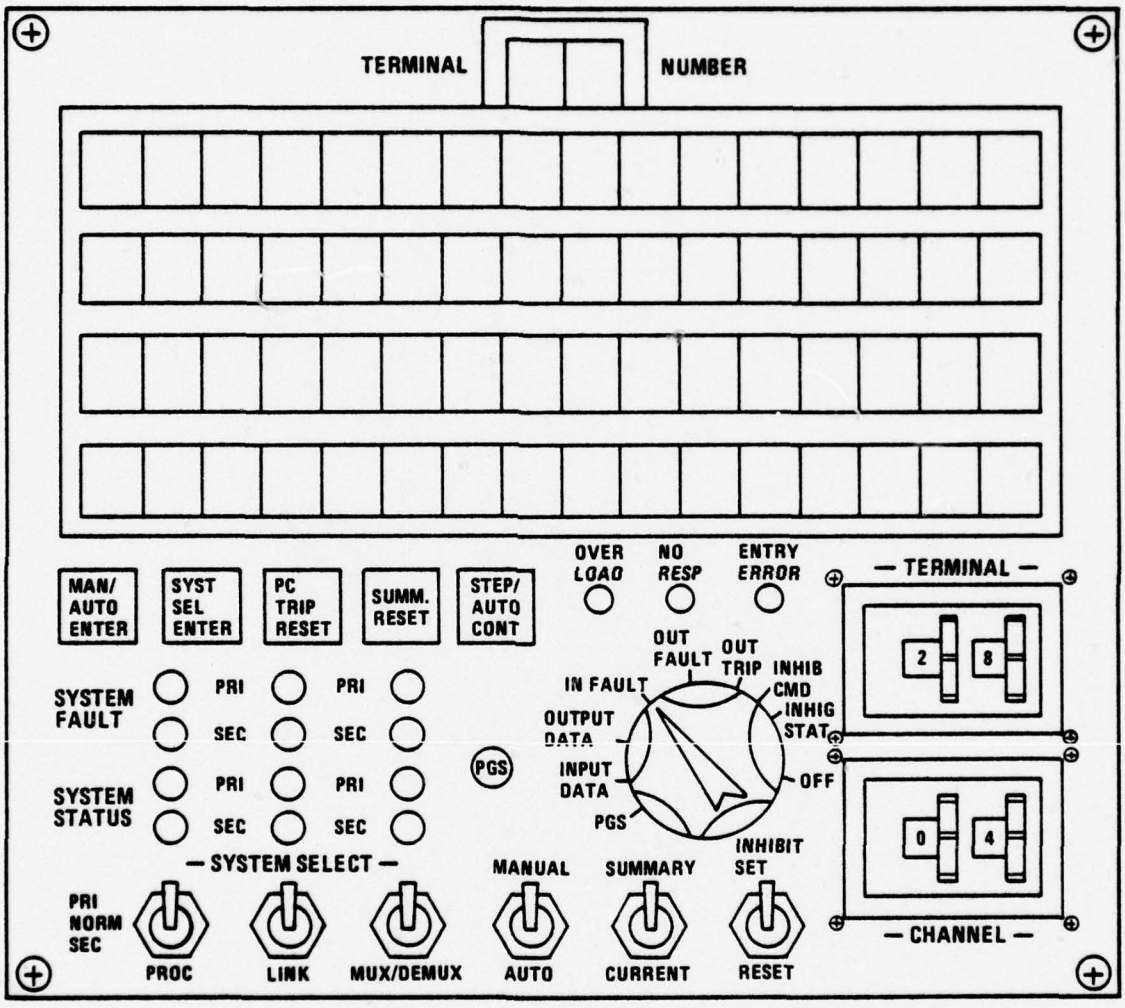


Figure 4-51. SOSTEL Crew Control Display Panel - Alpha Numeric Display and Rotary Switch

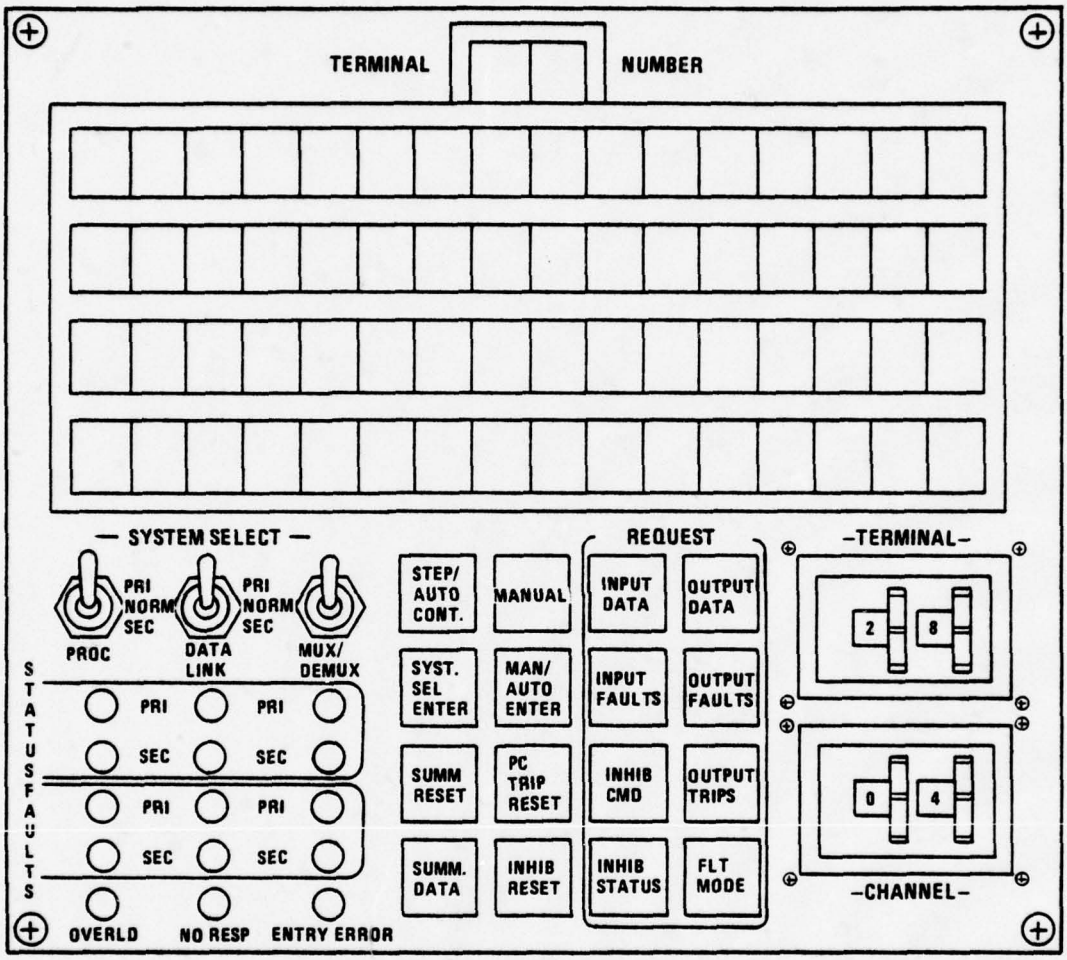


Figure 4-52. SOSTEL Crew Control Display Panel - Alphanumeric Display and Pushbutton Switches

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4.2.4.3.3 Crew Control/Display Panel I/O

The crew control/display panel interface with panel switches and display devices is accomplished by means of input/output logic contained within the CCDP MUX/DEMUX data terminal. Two CCDP panel configurations are examined from the point of panel switch/display I/O requirements.

Figure 4-53 represents an I/O which satisfies the SOSTEL specification CCDP. It is conceived as a bus-oriented I/O with strobed latching registers for output data. Output data to discrete LEDS, 4 x 16 display matrix, and numerical terminal number readout is held until new data from the bus is strobed into the register.

Figure 4-54 is a switch and display I/O arrangement for an alphanumeric CCDP panel. The I/O is bus oriented as in the previous case, and data on the bus is controlled by a microprocessor. Displays are multiplexed to reduce the quantity of display drive electronics. Panel switch information is buffered to the bidirectional bus by means of tristate devices. Strobe pulses, generated by the microprocessor, are used to enable the switch buffers and display latches during periods of data transfer.

Since the displays are multiplexed, an easy method of controlling display intensity is to control the duty cycle at which they are updated. This is accomplished by a controlled clock frequency used to interrupt the microprocessor. By varying the interrupt frequency, and holding the display update period constant, the duty cycle of the display update is controlled, hence the intensity of the display.

4.2.4.4 Interactive Alphanumeric Display Panel

The aircraft crew requires information on the status of the electric generation and distribution system (AAES). They also must have the ability to override the master unit and turn on or off selected functions. In a operational vehicle, these functions could be performed by the AIMIS/MMD and keyboard. During lab integration and flight test a similar capability is required, both to monitor and control the system and evaluate the interface between the pilot and the system.

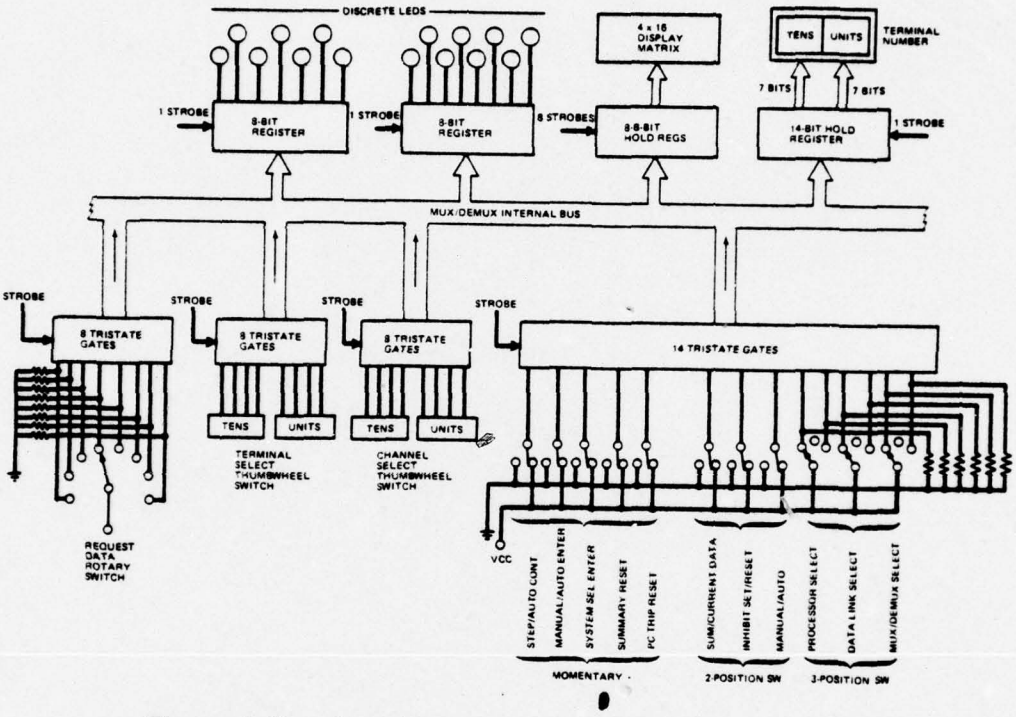


Figure 4-53. Sostel Crew Control Display Panel I/O

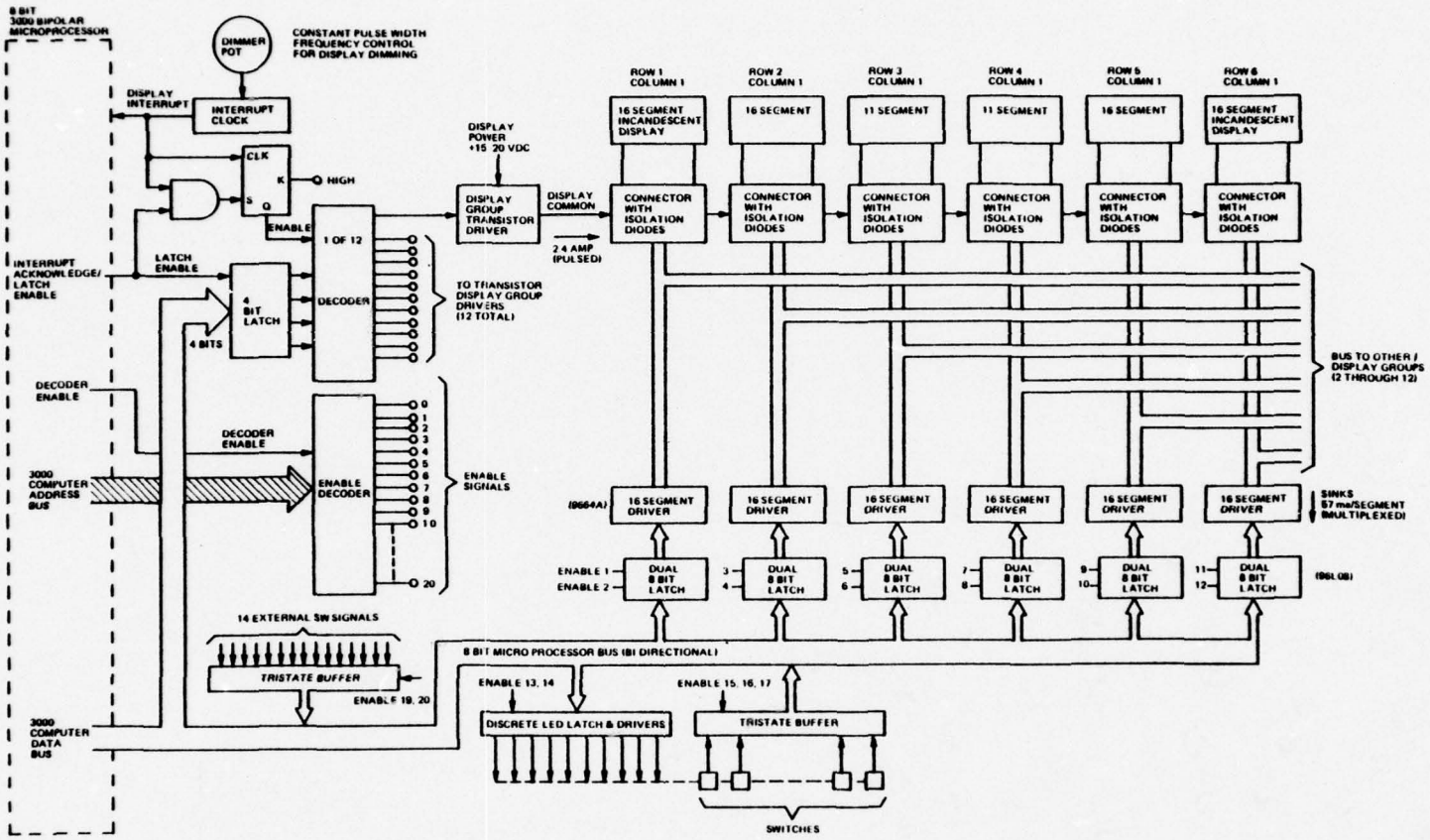


Figure 4-54. Interactive Alphanumeric Panel I/O

Two proposed approaches are covered. The first is a 72-character alphanumeric interactive display panel. The second (pilots panel) is a limited version of the first; it has fewer controls and only 24 alphanumeric characters. An interactive approach for operational control and display of SOSTEL data reduces the number of panel controls with which the pilot must become familiar. The SOSTEL processor plays a stronger role in this configuration, thus relieving the operator of much of the thought process necessary to operate the CCDP panel arrangements. The master unit controls all data presented on the display. Therefore, when a fault is detected it is automatically displayed.

The display panel in Fig. 4-55 provides the capability to display multiple failures on a priority basis.

The display panel device performs both a control and a display function. Ten program switches are used in conjunction with the display to implement the selection of control functions. For example; the title block would display SELECT FUNCTION which is abbreviated as SELECT FUNCT. The remainder of the display would show up to 10 options available under the SELECT FUNCT title. These would be displayed as follows:

OFF	PGS MON (Power generation system monitor)
INHCMD (Inhibit command)	INHSTA (Inhibit status)
INDATA (Input data)	OUTDAT (Output data)
INFLT (Input faults)	OUTFLT (Output fault)
	OUTTRP (Output trip)

At this point, the operator has a choice. He may select one of the displayed options by depressing the corresponding program switch and hitting the enter button. The second choice is not to make any selection of the displayed options by hitting the step/auto continue button. This action would cause the system to step to the next primary title block in the manual mode or search for faults and trips in the automatic mode.

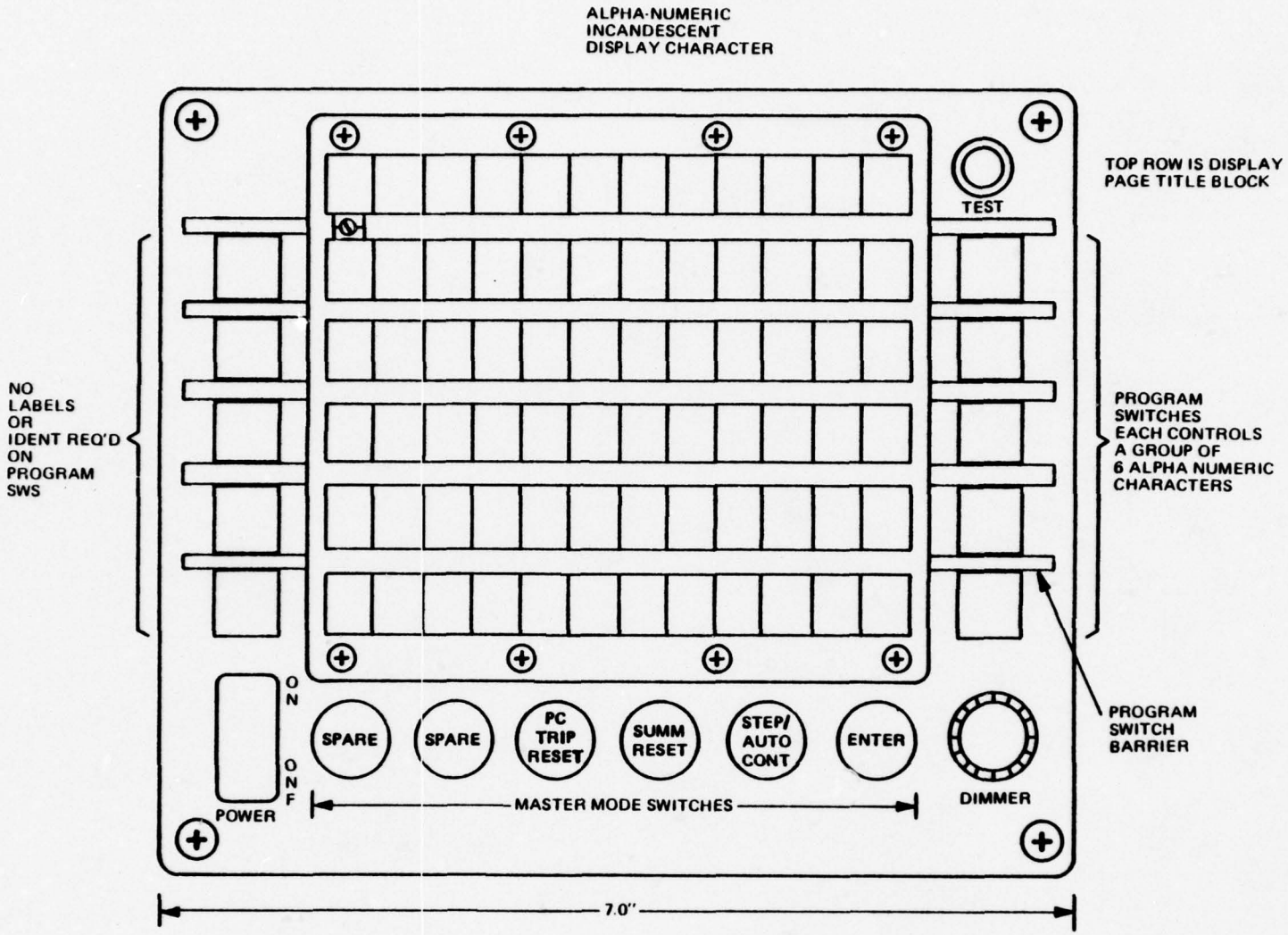


Figure 4-55. Interactive Alphannumeric Control/Display Panel

If one of the displayed options is selected, the program would next display the selected option in the title block and display either data or secondary control functions to be selected.

4.2.4.4.1 Interactive Control/Display Functions

The control/display functions which would be mechanized for SOSTEL control on the interactive display are listed in Table 4-42. Under the "Primary Control Functions" of that table are the control titles required for SOSTEL. For each, there is an associated set of options provided for operator selection.

Listed in the category of primary functions of Table 4-42 are title block identifiers and displayed items associated with each identifier. Secondary control functions are required for most selected control options. These are displayed once a primary option has been selected. For example, if the input data option is selected, a secondary option would be to select terminal number. "SELECT TERM" would appear in the title block and terminal numbers presented as options.

4.2.4.4.2 Typical Interactive Display Formats

Formats of display data for the interactive type of control/display panel are described. The alphanumeric control/display functions of Table 4-42 are formatted into a 72-character alphanumeric display capability.

A 12-character title block provides sufficient capacity to legibly display two-word titles without severe truncation. The following five rows of displays may either be separated into two groups of six characters each per row, or the entire 12-character row may be used for messages.

Figures 4-56 through 4-65 illustrate both the primary control functions and primary display functions listed in Table 4-42.

4.2.4.4.3 Interactive Display Panel Flow

Primary control and primary display functions of Table 4-42 form the basis of the control/display flow diagram of Fig. 4-66. The loop cycles through the four primary control functions and four display functions indicated in Table 4-42, and

TABLE 4-42. F-14 AAES SOSTEL ALPHANUMERIC CONTROL/DISPLAY FUNCTIONS

Primary Control Functions		Primary Display Functions	
Title	Option	Title	Display
Select Function	OFF	System Status	Computer 1
	INHIBIT STATUS		Computer 2
	INHIBIT COMMAND		Link 1
	OUTPUT TRIP		Link 2
	OUTPUT FAULT		
	INPUT FAULT	System Fault	Computer 1
	OUTPUT DATA		Computer 2
	INPUT DATA		Link 1
	PGS MONITOR		Link 2
Select System	Computer 1		OVERLOAD
	Computer 2		NO RESPONSE
(No Secondary Select Functions)	Computer Normal		ENTRY ERROR
	Link 1		PGS
	Link 2	MUX/DMUX Status	Select Terminal
	Link Normal		Terminal No.
Select Mode	Manual		Primary or
	AUTO		Secondary
	Summary	MUX/DMUX Fault	Terminal No
	Current		Primary or
	INHIBIT SET		Secondary
	INHIBIT RESET		
Select MUX/DEMUX	Select Terminal		
	Select Primary		
	Select Secondary		
	Select Normal		

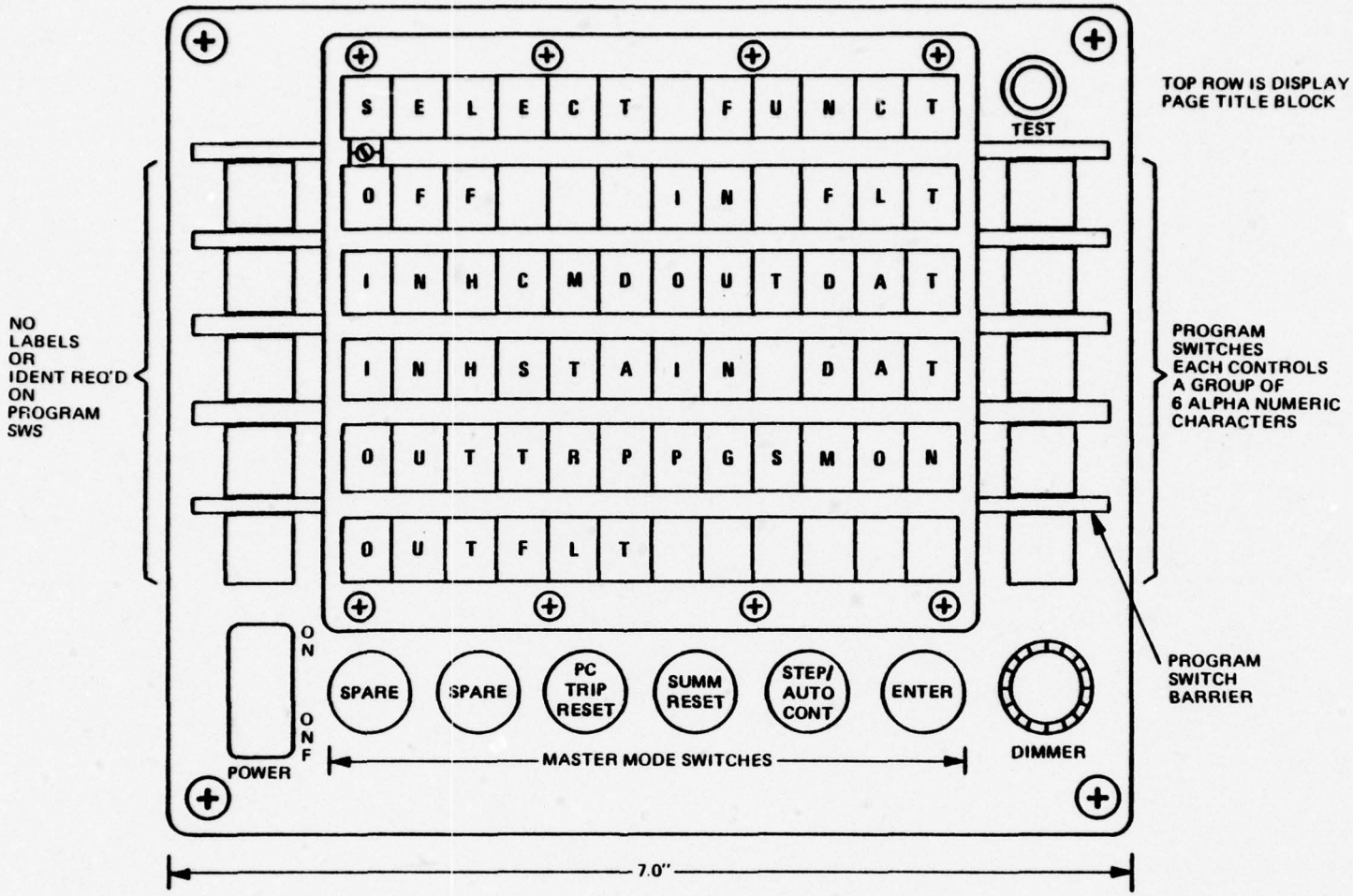


Figure 4-56. Select Function

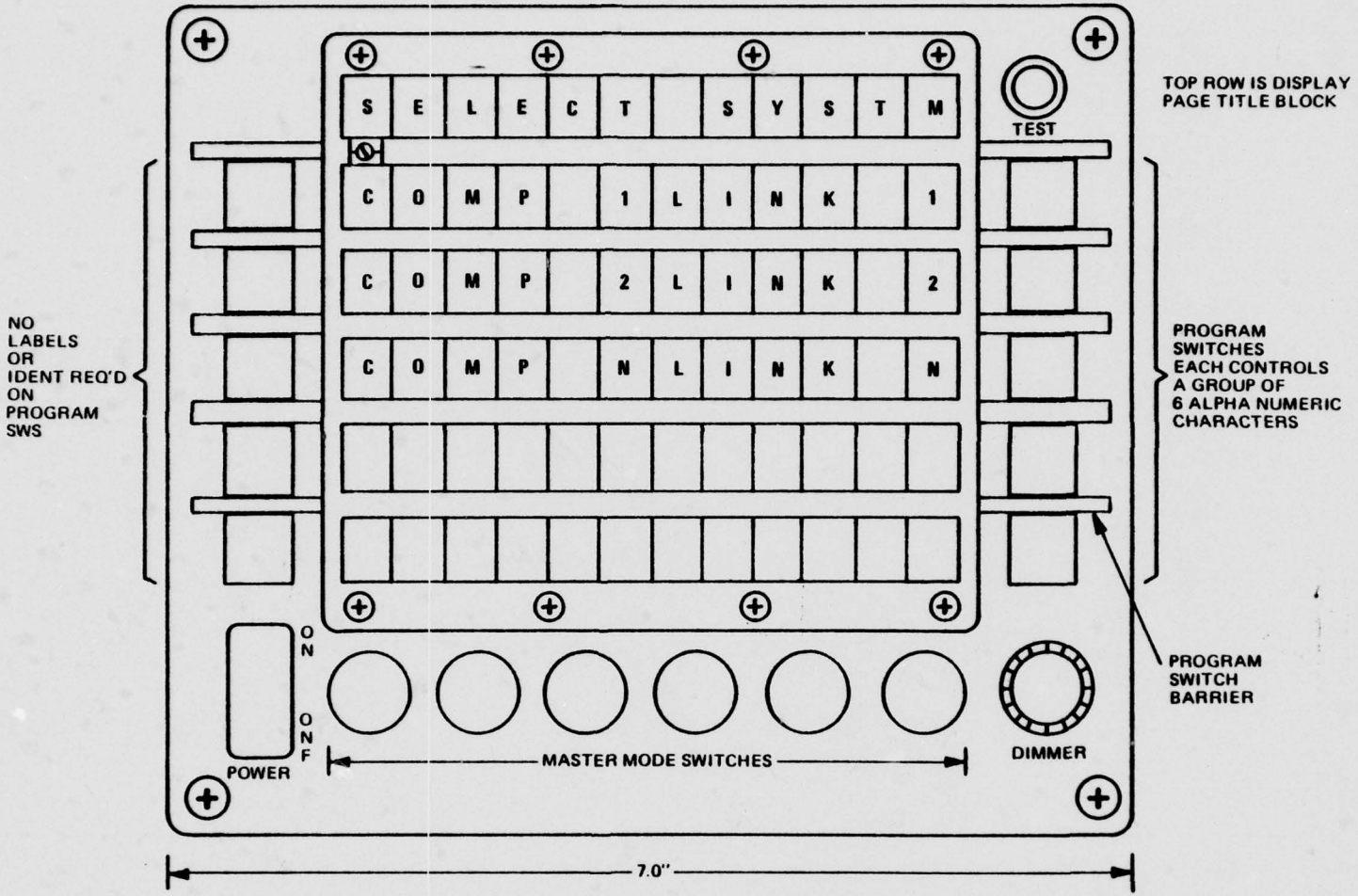


Figure 4-57. Select System

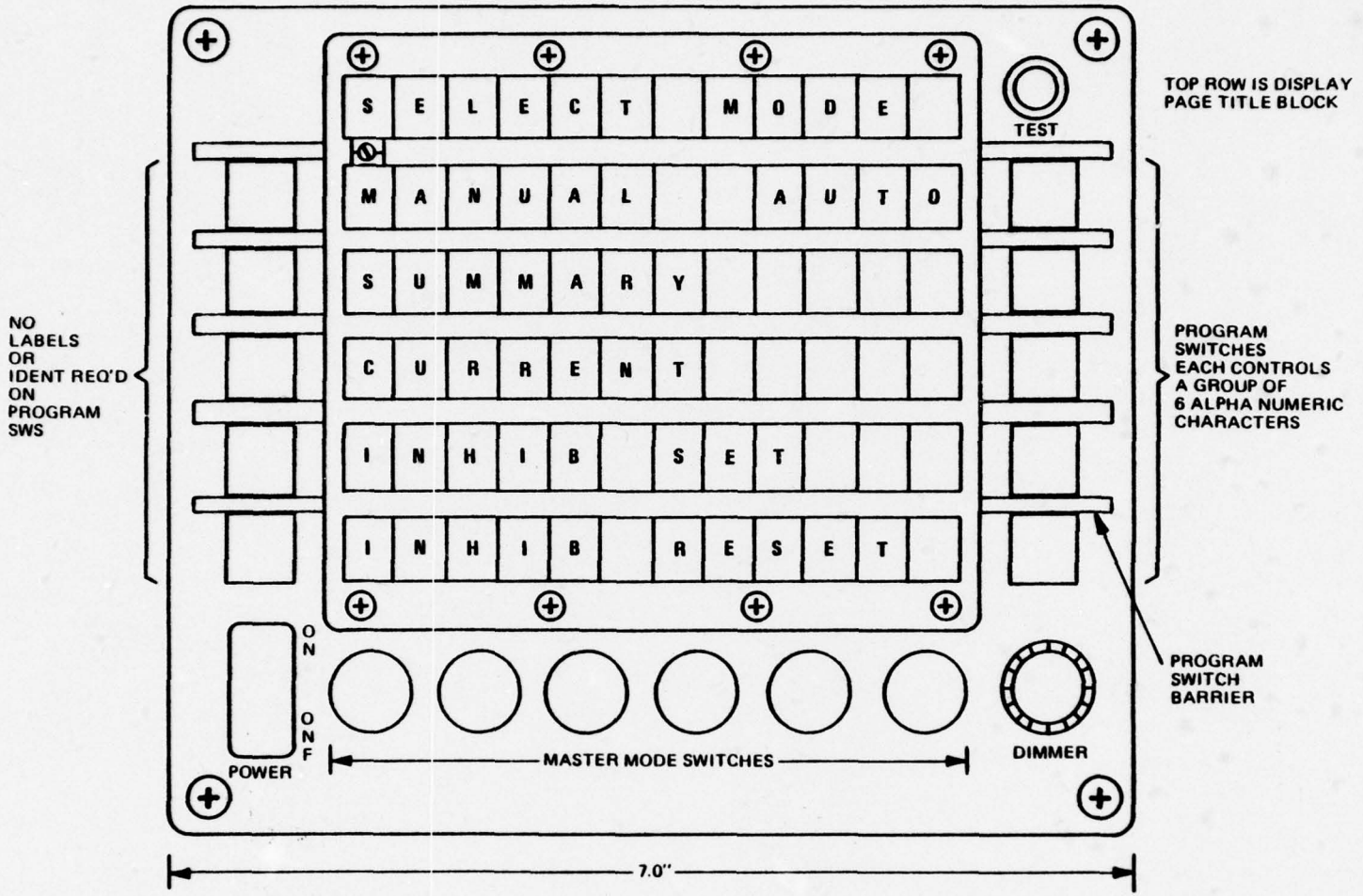


Figure 4-58. Select Mode

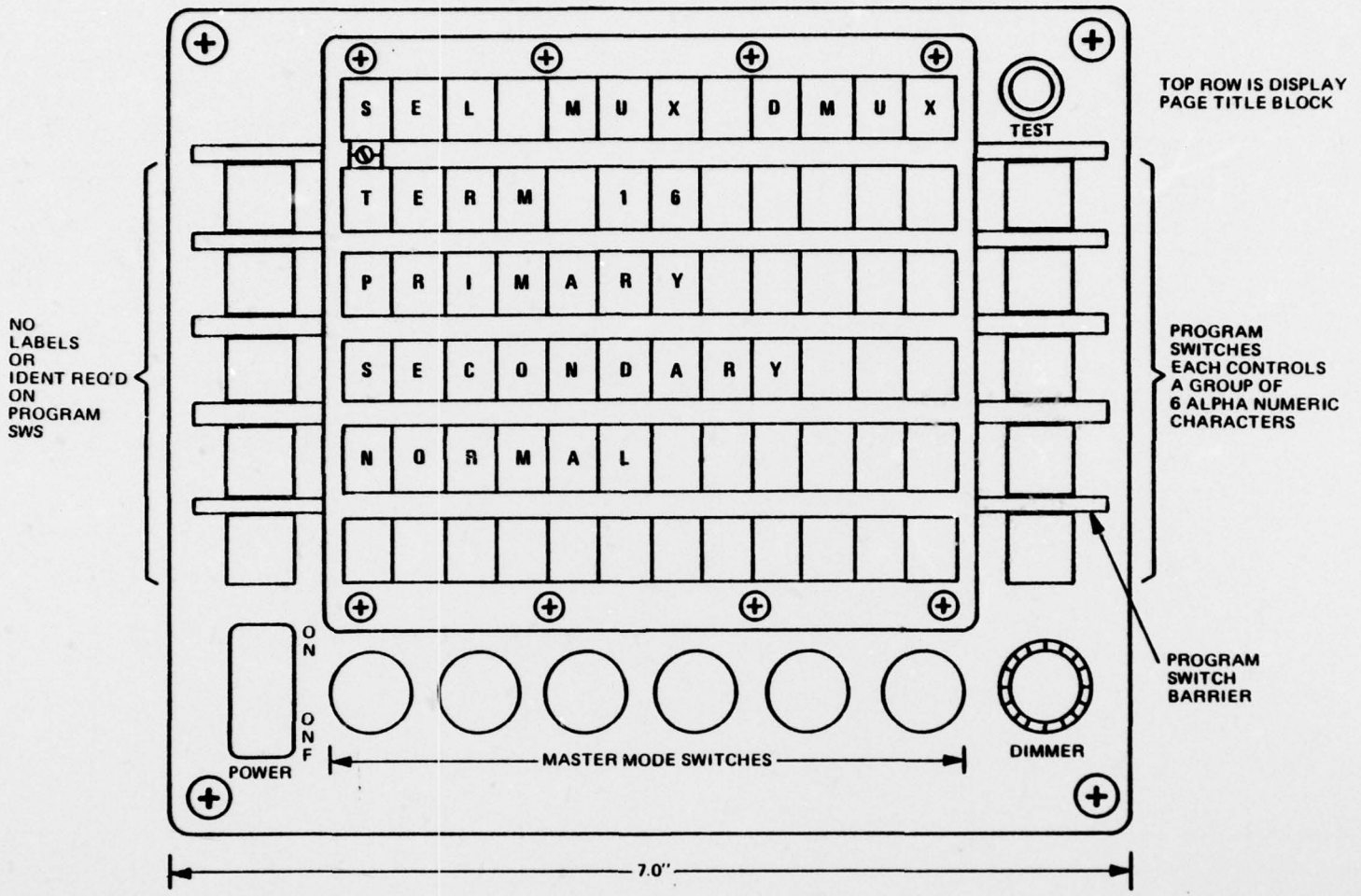


Figure 4-59. Select MUX-DEMUX

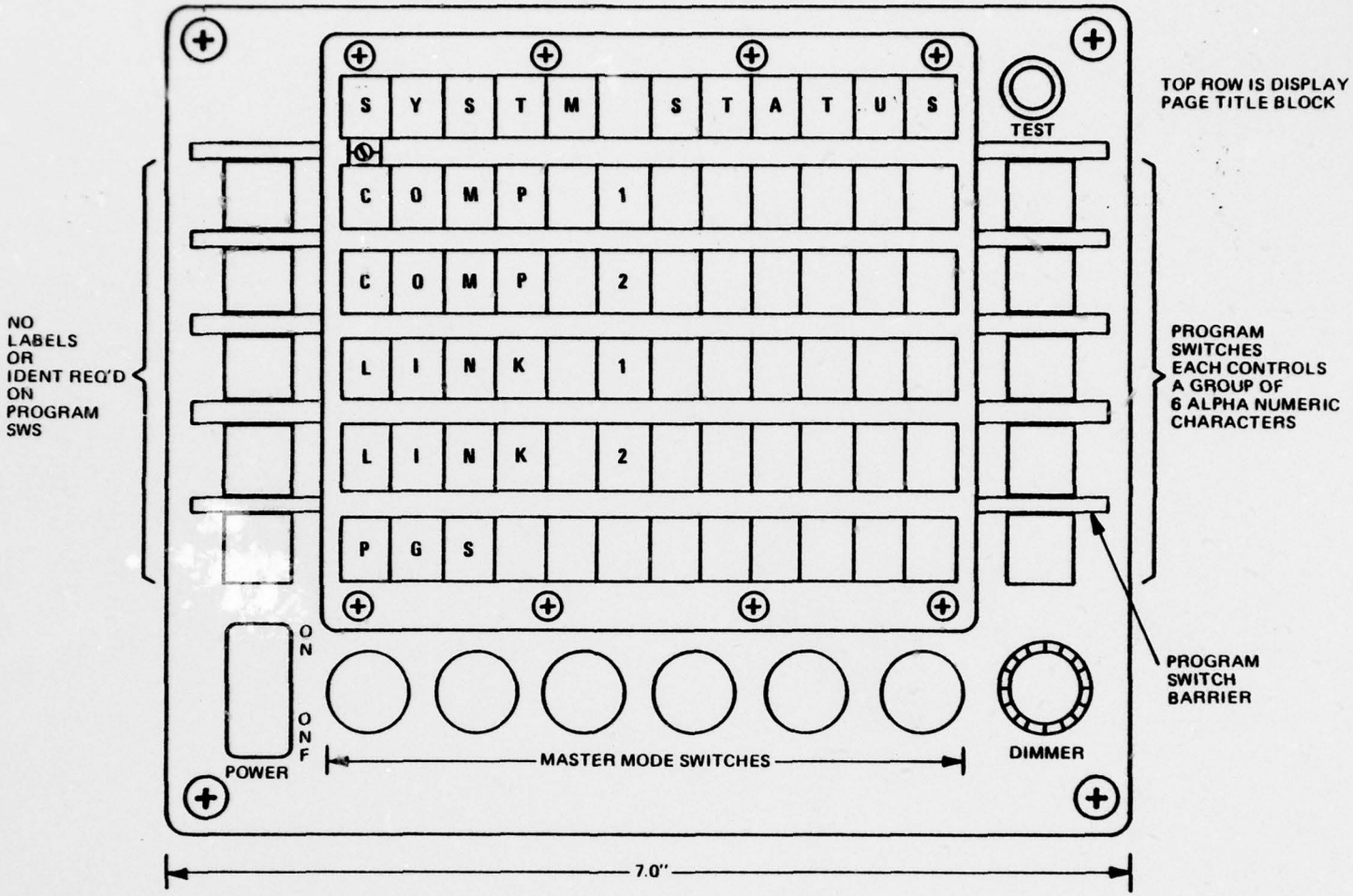


Figure 4-60. System Status

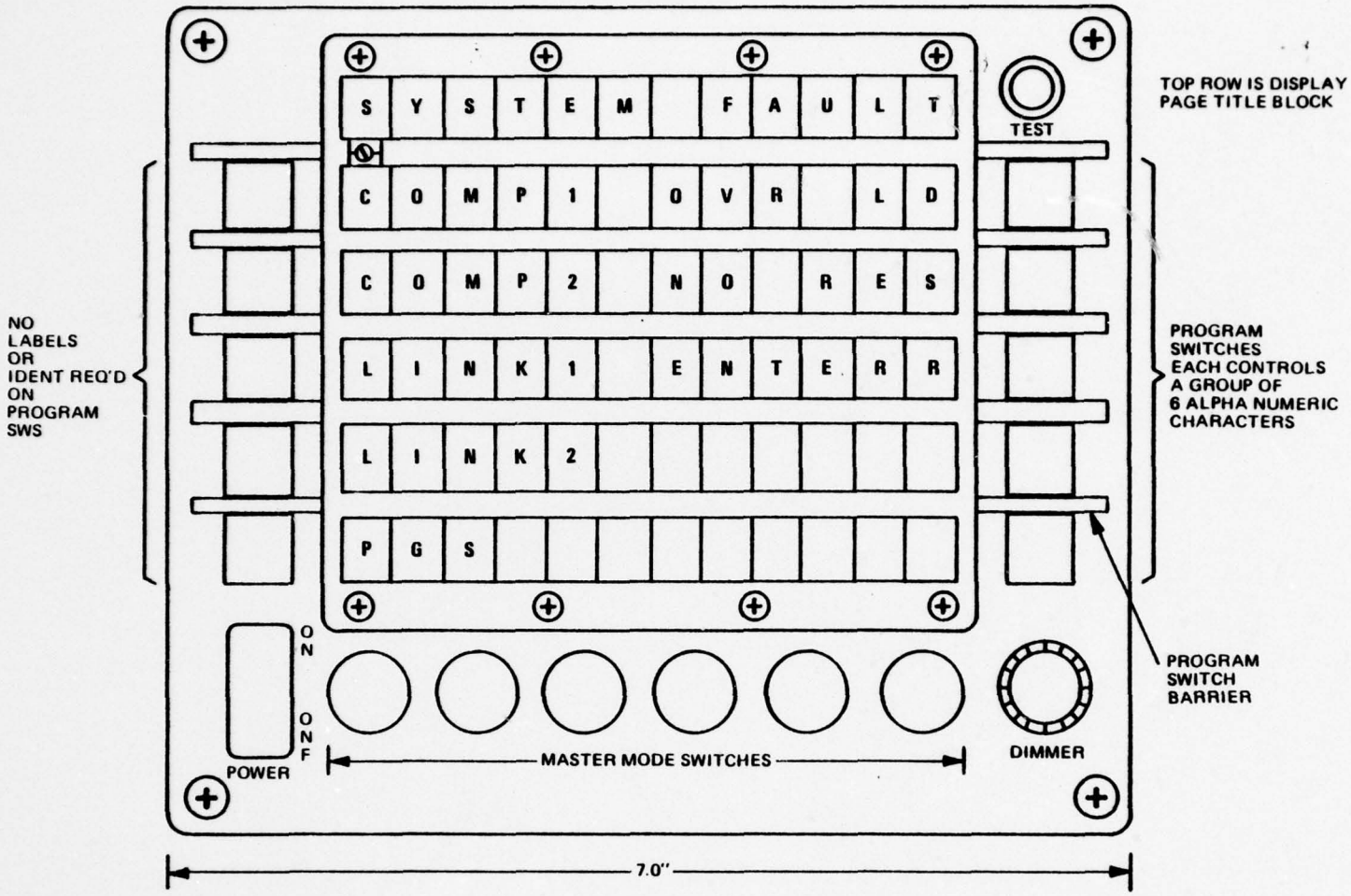


Figure 4-61. System Fault

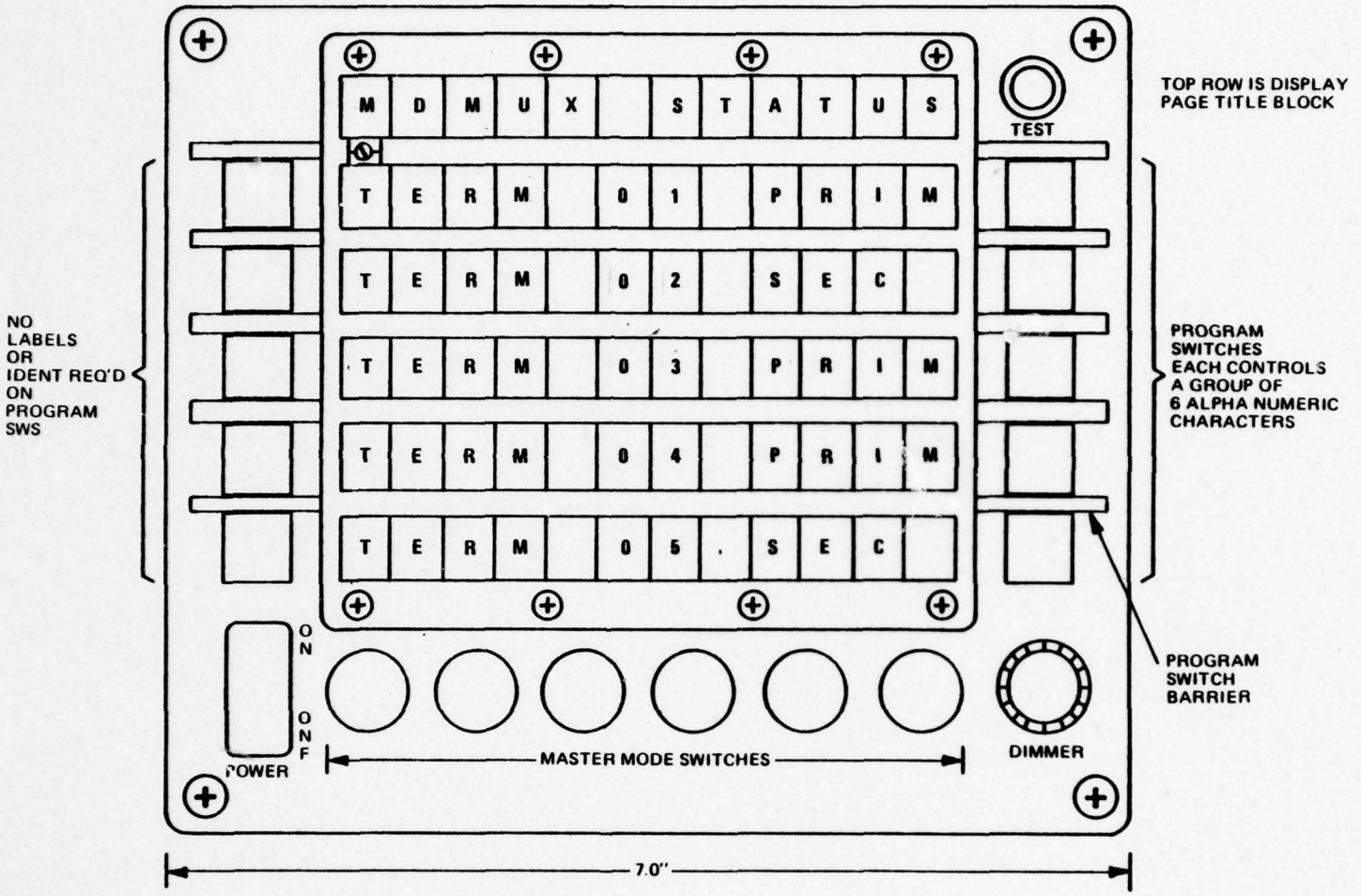


Figure 4-62. MUX/DEMUX Status

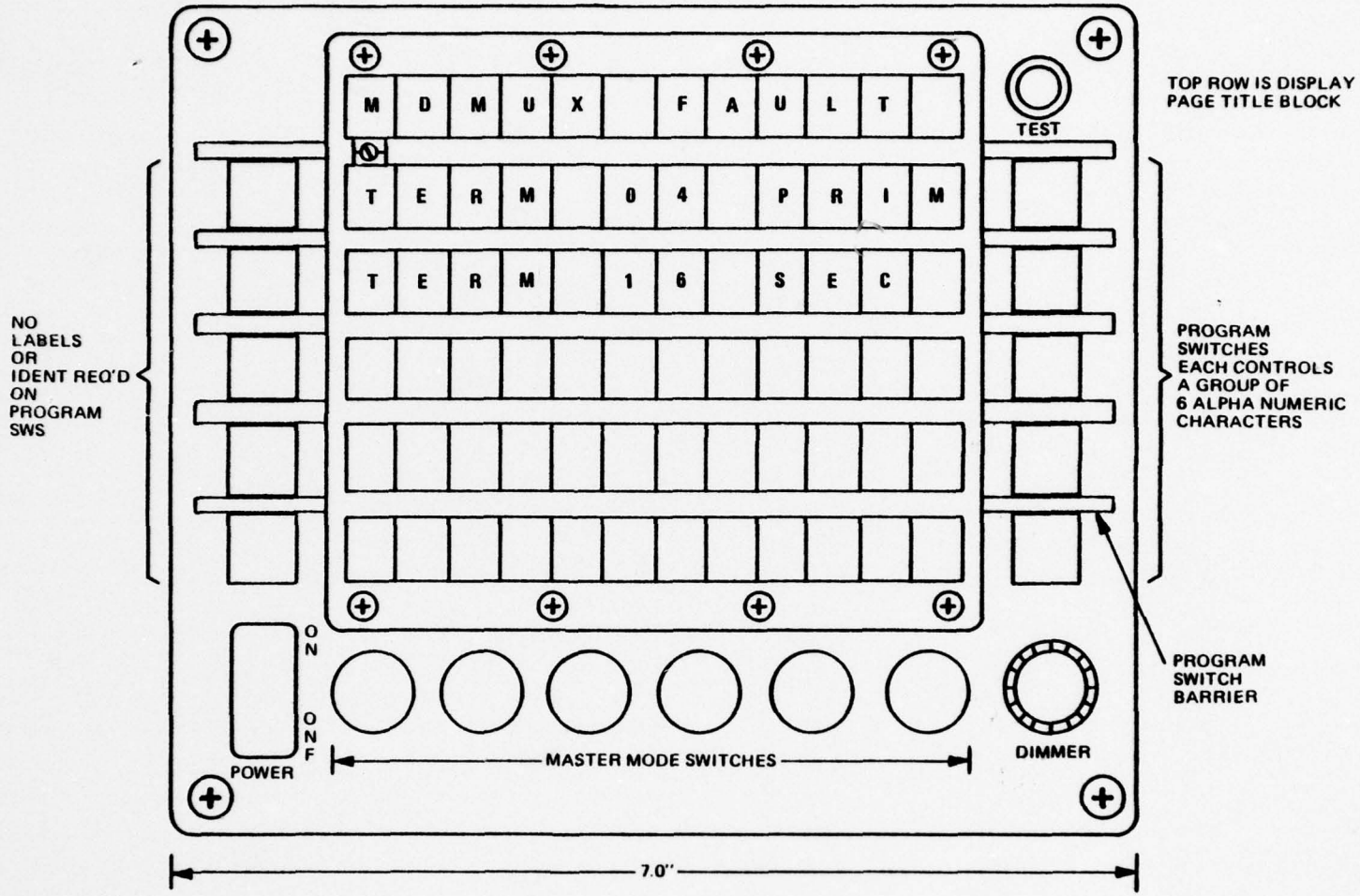


Figure 4-63. MUX/DEMUX Fault

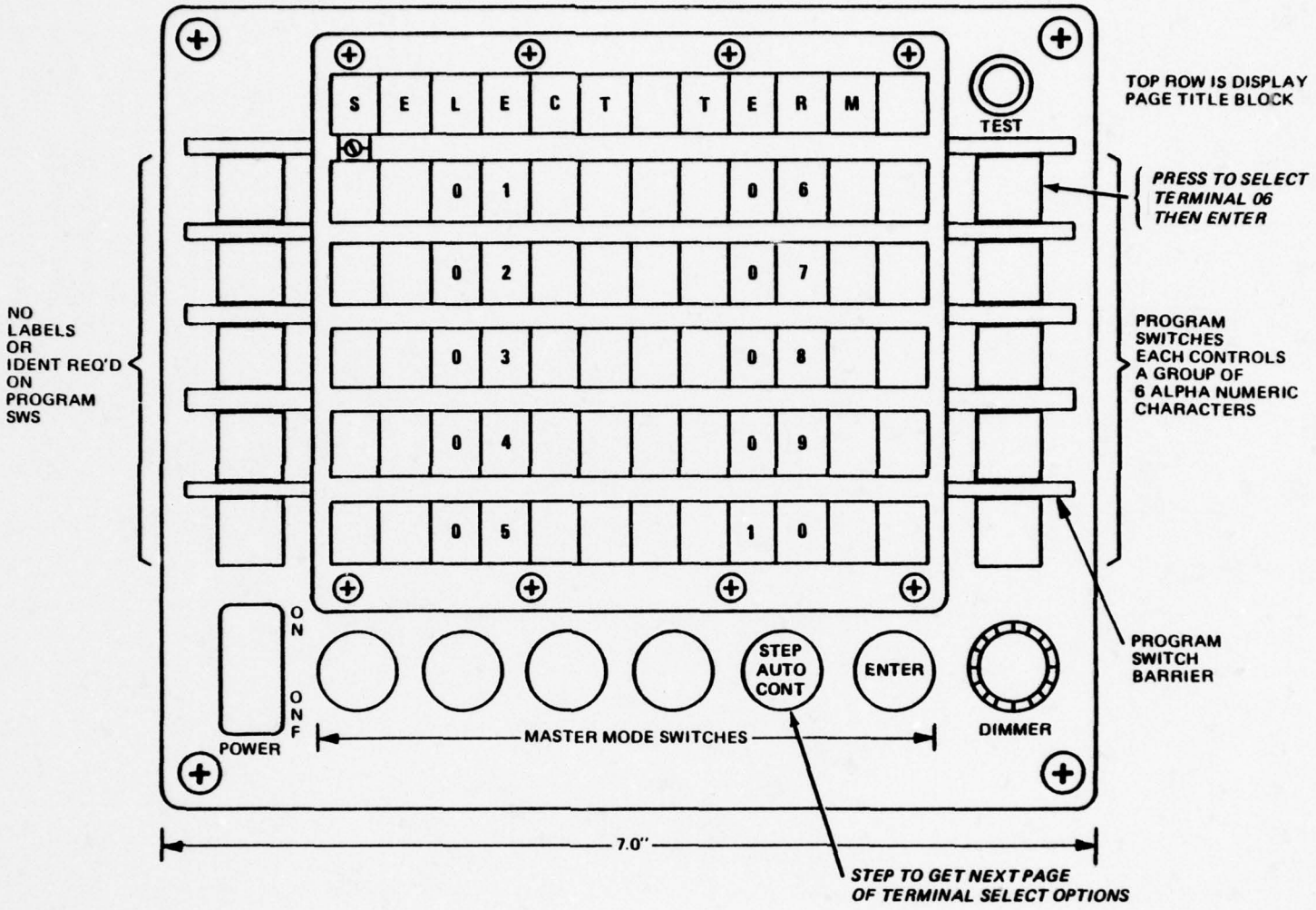


Figure 64. Select Terminal

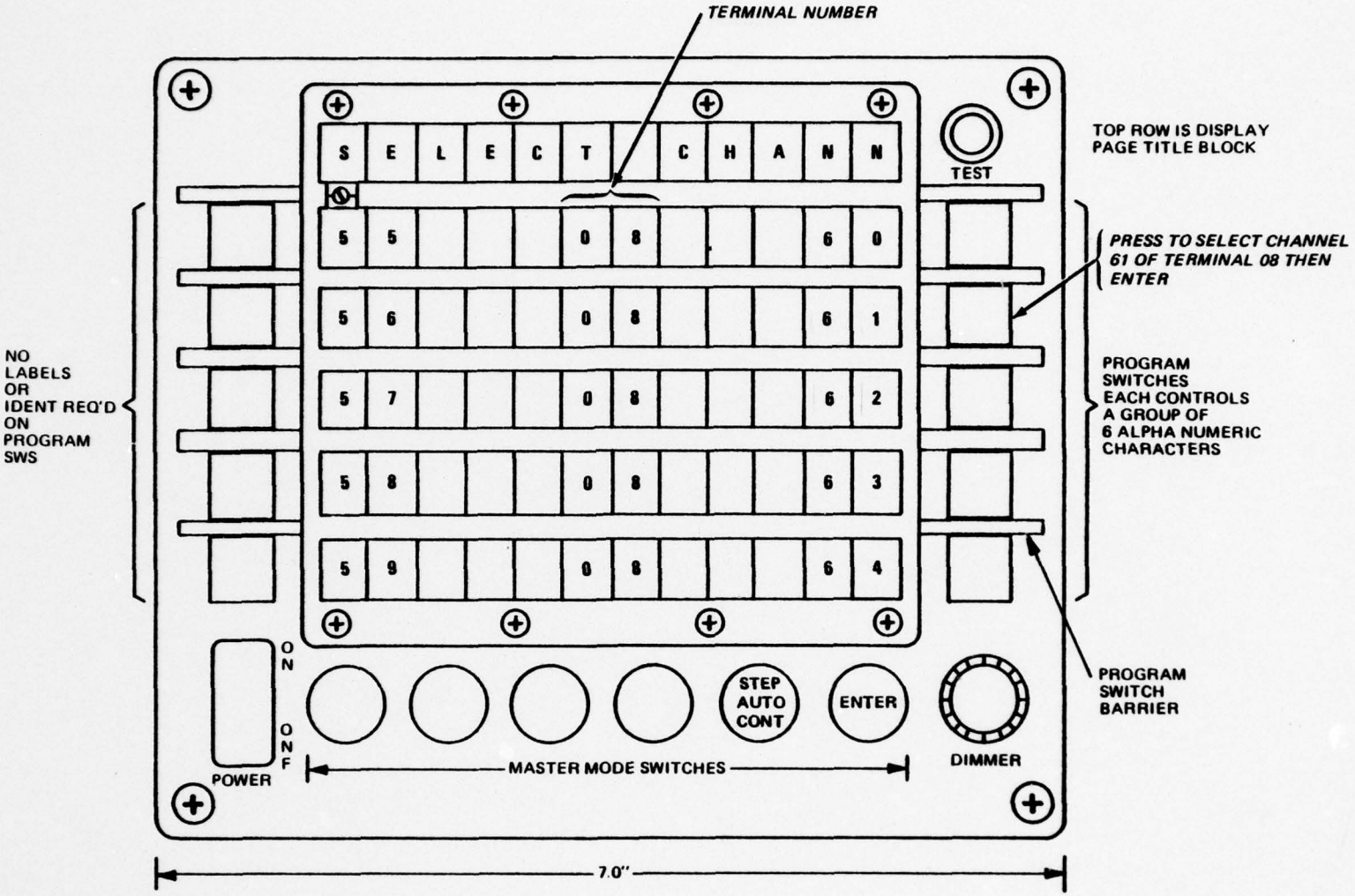


Figure 4-65. Select Channel

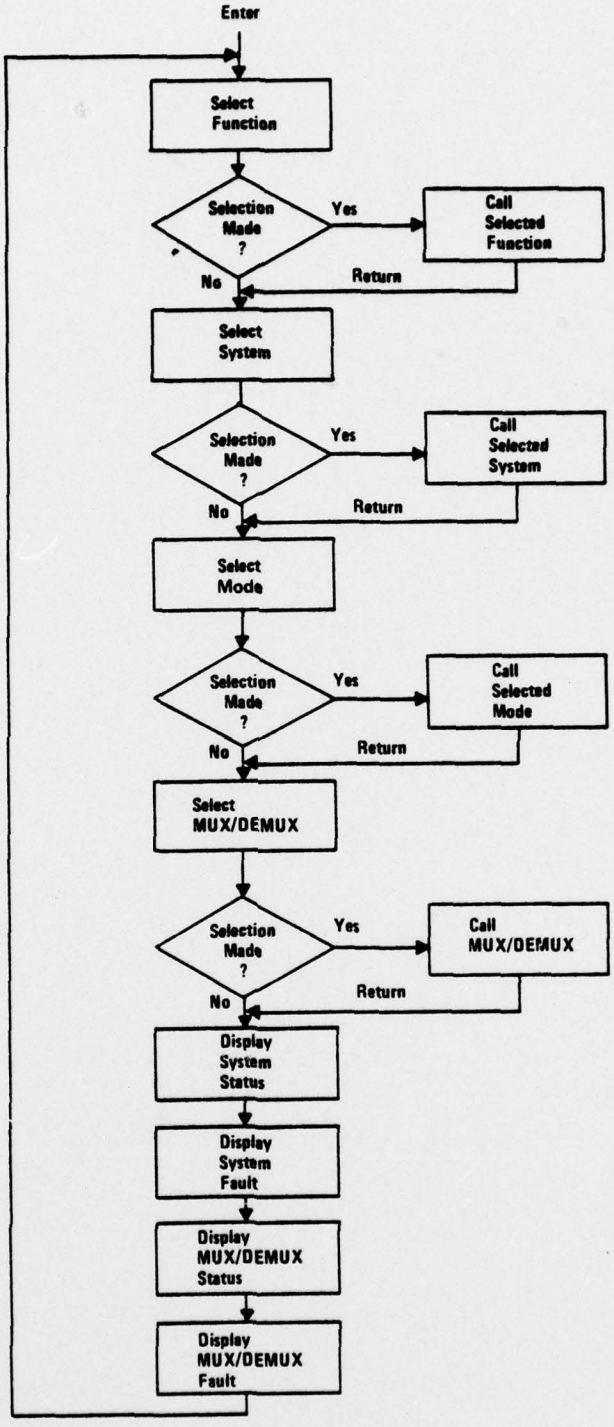


Figure 4-66. SOSTEL CCDP Control/Display Flow Diagram

as each function is cycled to the display, the title block is displayed for each. For control functions, the options available for selection are displayed along with the title block. For primary display functions, no selection options are available, but display information is displayed under the title block.

As each primary control function is displayed the operator has the choice of selecting one of the displayed options, or allowing it to pass. If in the manual mode, the operator must depress the step/auto continue switch to step the display to indicate the next page of data in the cycle. If the system is operating in the automatic mode, the display will automatically step through the display functions, allowing sufficient time for the operator to select an option of a displayed control function.

Whenever the operator makes an option selection, the program controlling the operation of the panel calls the subroutine associated with the selected option. After completion of the subroutine processing, control returns to the control/display flow chart of Fig. 4-66. Figure 4-67 illustrates the logic related to option selections associated with SELECT FUNCT. Figure 4-68 is the logic for SELECT SYSTEM. Figure 4-69 shows the logic for SELECT MODE. SELECT MUX/DEMUX logic is illustrated in Fig. 4-70. Figures 4-67 to 4-70 therefore cover the logic requirements for primary control functions.

Primary display function logic is included as Fig. 4-71 to 4-74 for SYSTEM STATUS, SYSTEM FAULT, MUX/DEMUX STATUS and MUX/DEMUX FAULT, in that order.

4.2.4.5 Pilots Panel

A limited interactive display and control panel particularly oriented to display and control failure conditions in the SOSTEL system is illustrated in Fig. 4-75. The display/control functions are tabulated in Table 4-43. This panel is designed to provide the pilot with an easily interpreted display and enable him to make rapid control decisions. The unit contains two 12-character alphanumeric lines of display similar to the previously discussed interactive display. A FAULT display would indicate in

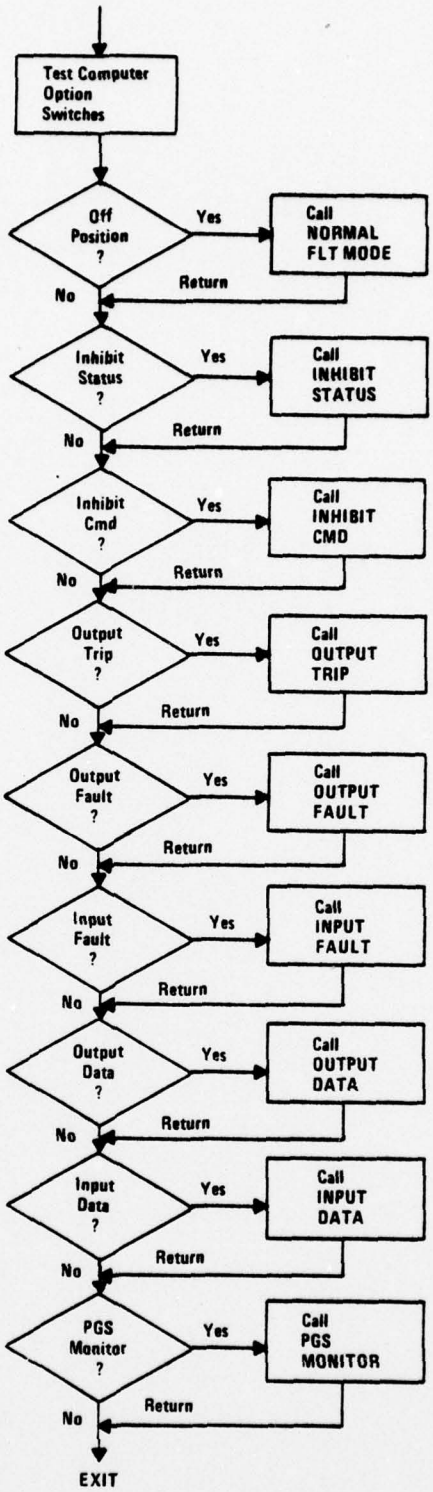


Figure 4-67. Select Function Flow Diagram

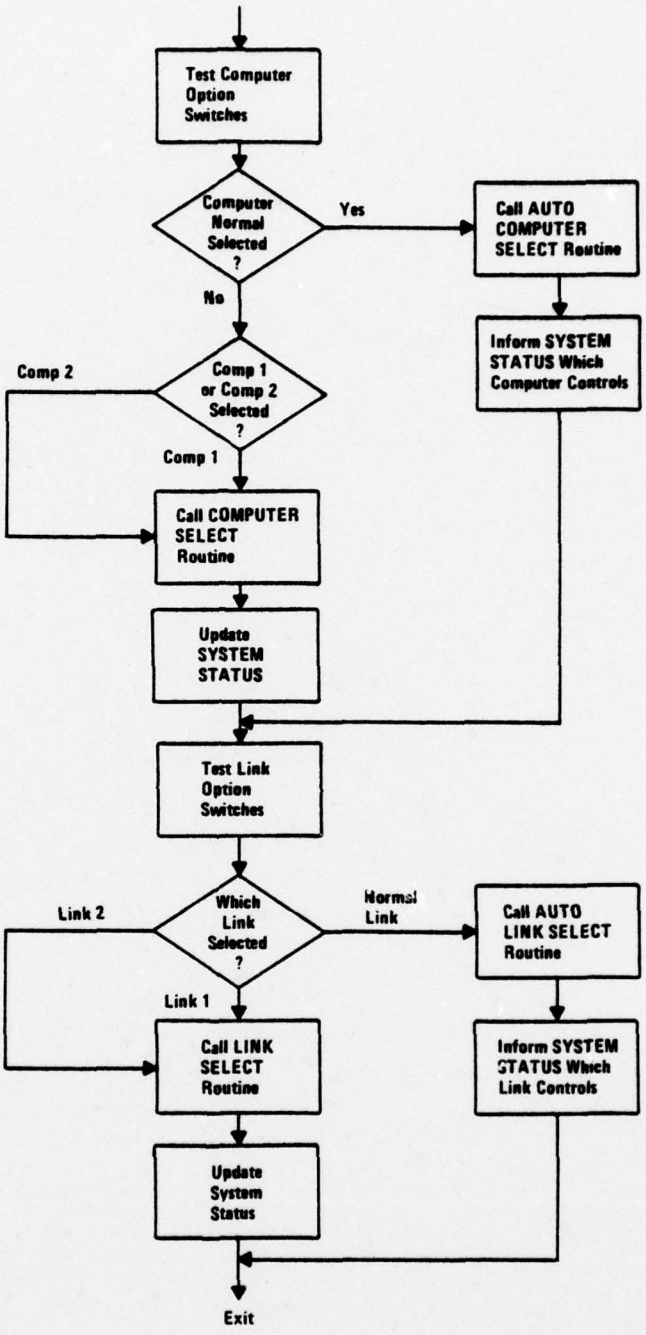


Figure 4-68. Select System Flow Diagram

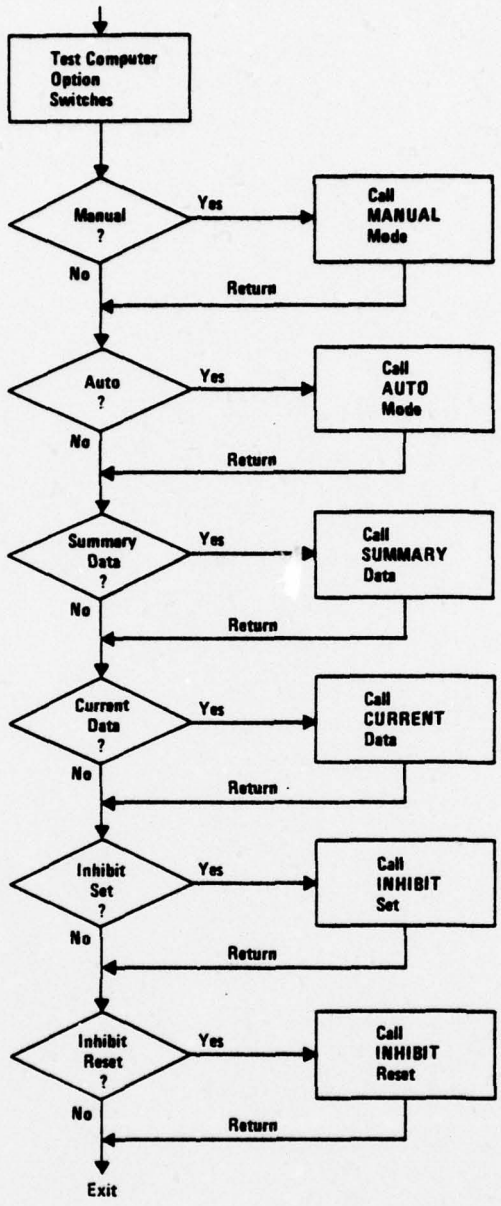


Figure 4-69. Select Mode Flow Diagram

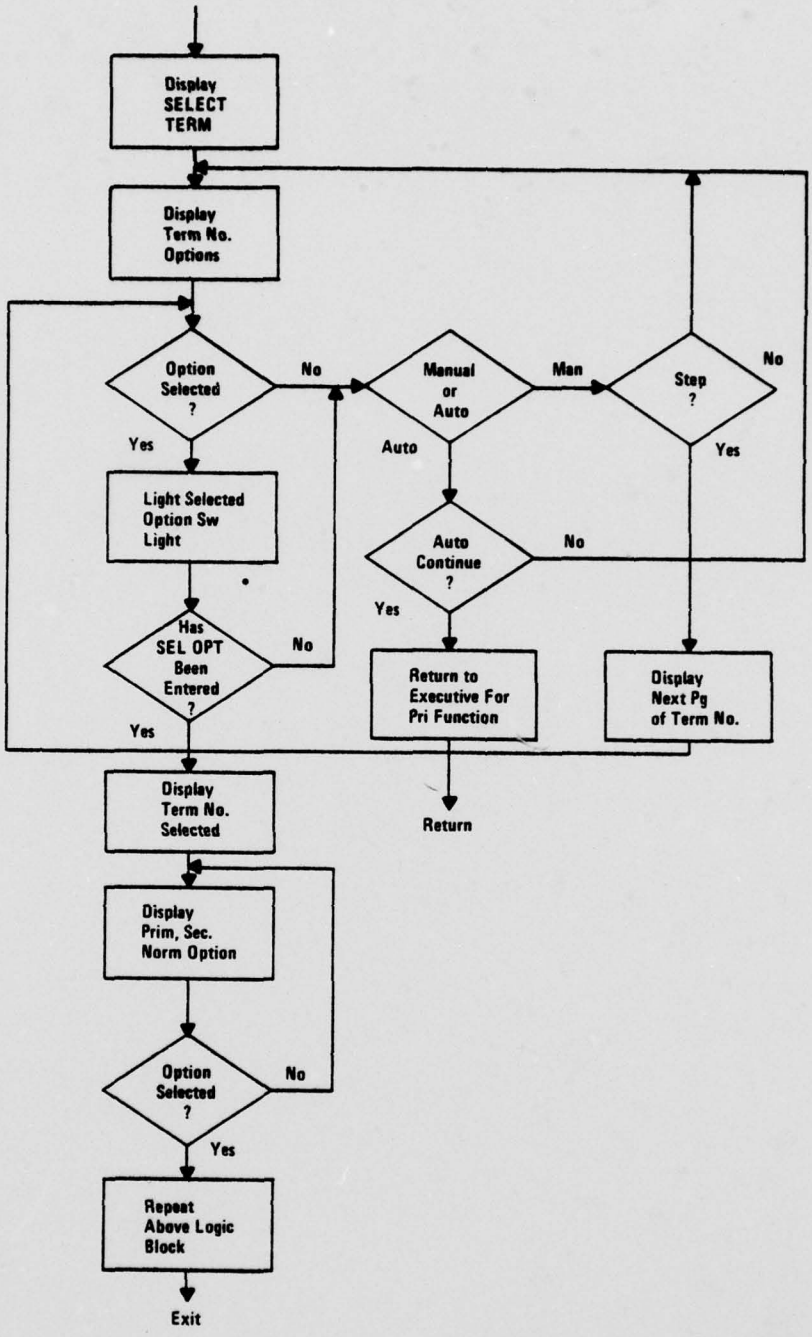


Figure 4-70. Select MUX/DEMUX Flow Diagram

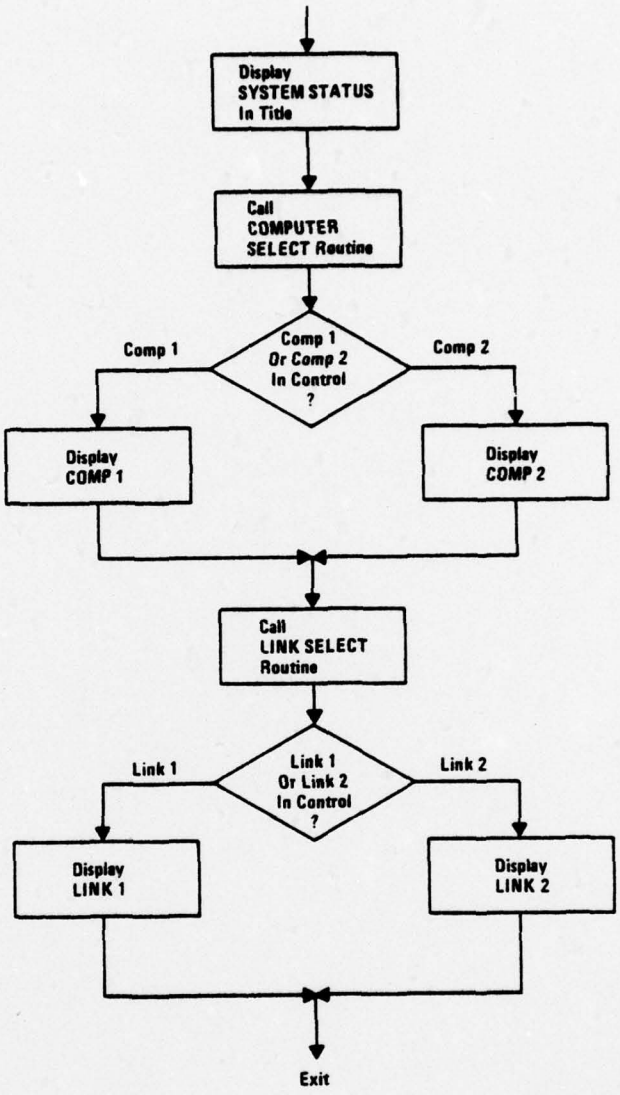


Figure 4-71. Display System Status Flow Diagram

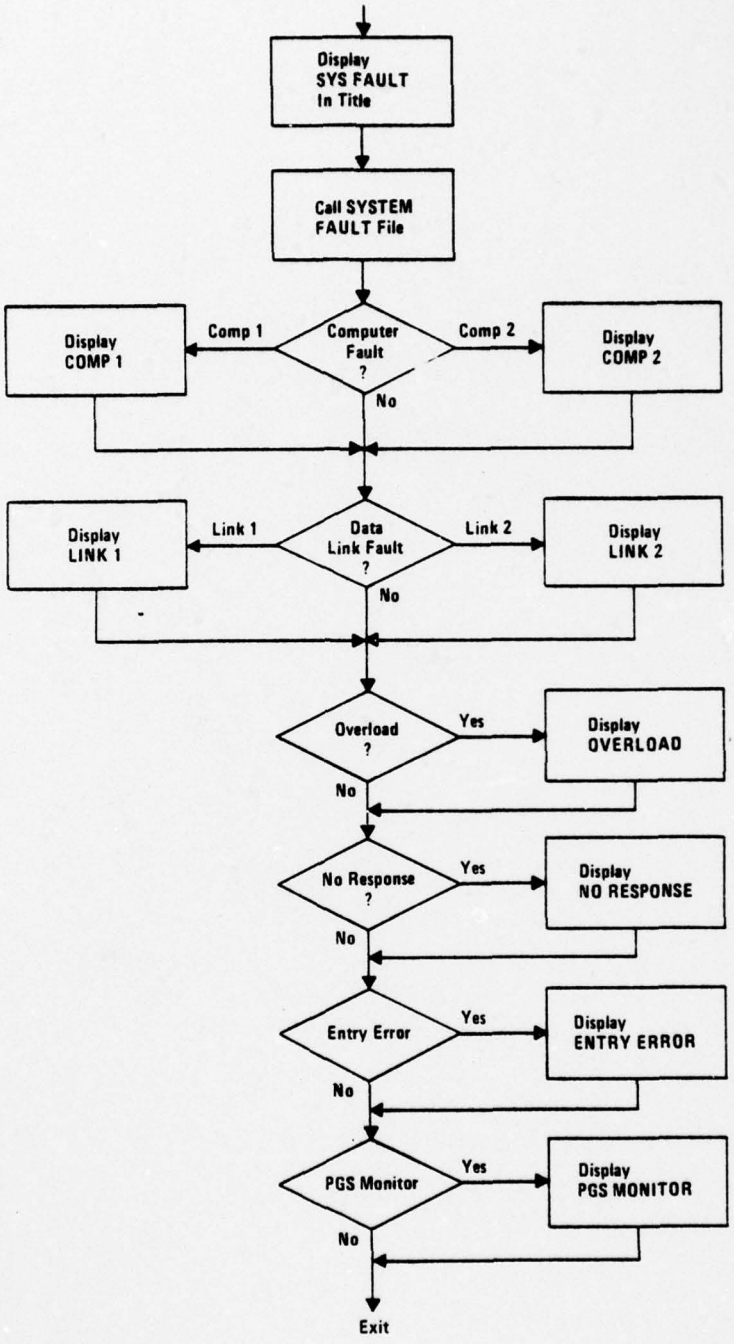


Figure 4-72. Display System Fault Flow Diagram

AD-A047 859 GRUMMAN AEROSPACE CORP BETHPAGE N Y F/G 9/3
ADVANCED AIRCRAFT ELECTRICAL SYSTEM (AAES). DEFINITION AND PROT--ETC(U)
JUL 76 G COTTER, H SIEGEL, P PISANI N62269-75-C-0392
UNCLASSIFIED NADC-76194-30-VOL-1 NL

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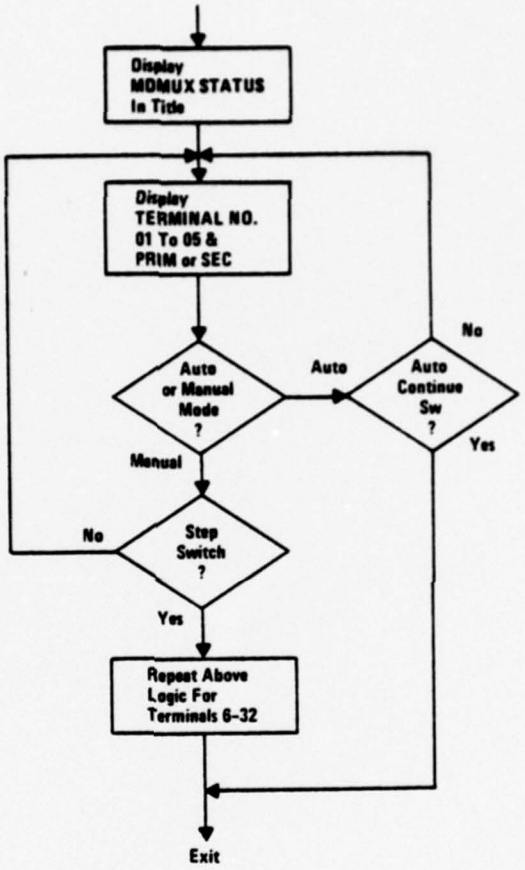


Figure 4-73. Display MUX/DEMUX Status Flow Diagram

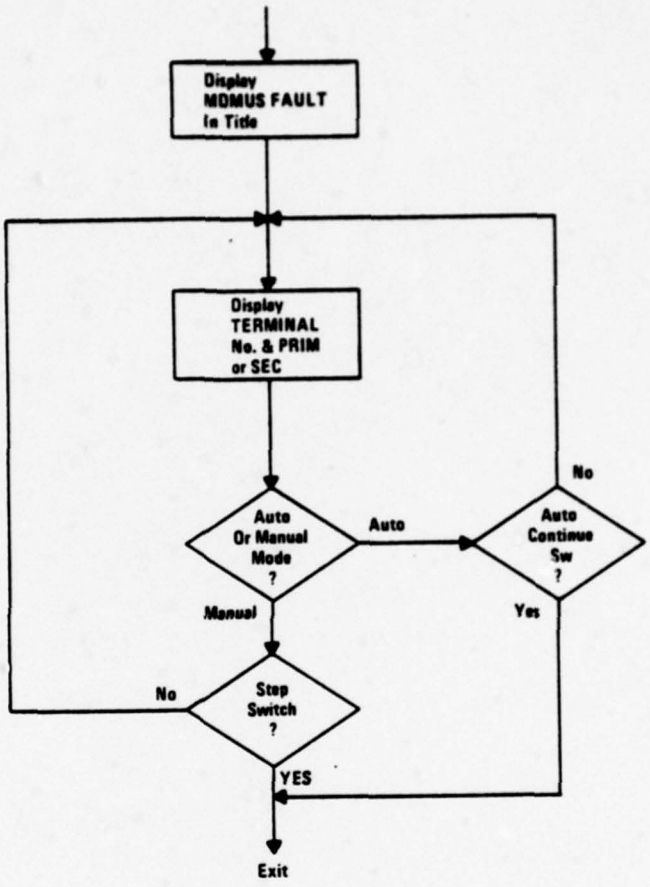


Figure 4-74. Display MUX/DEMUX Fault Flow Diagram

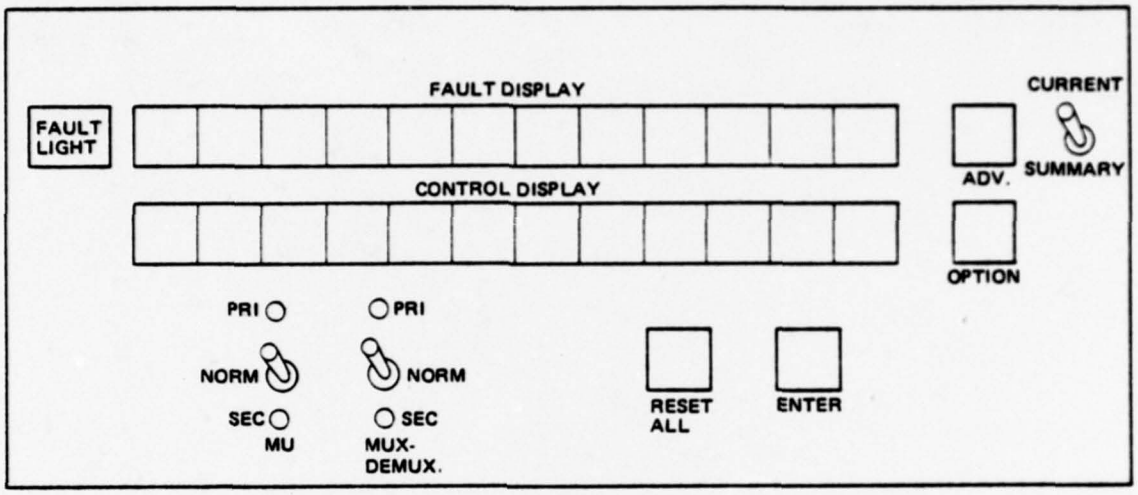


Figure 4-75. Pilots Panel

TABLE 4-43. PILOTS PANEL DISPLAY/CONTROL FUNCTIONS

Display/Control	Function
Fault Light	Light indicates fault, alphanumeric contains new fault condition
Fault Alphanumeric Display	Displays fault condition in mneumonics
Control Alphanumeric Display	Displays pilot options relative to fault display
PRI/SEC Lights	Indicate failure of MU or MUX-DEMUX
PRI/NORM/SEC Toggle Switches	Controls switching of MU and block switching of MUX-DEMUX units
Current/Summary Toggle Switch	Controls whether new or old fault conditions are to be displayed
Advance Pushbutton	Advances the display to the next fault condition
Option Pushbutton	Allows incrementing options to be displayed on the control alphanumeric display
Reset All Pushbutton	Initiates reset of all tripped SSPC's
Enter Pushbutton	Initiates action to force the faulted parameter to the condition selected on the control alphanumeric display.

alphanumeric mneumonics the nature of the fault condition. A CURRENT/SUMMARY toggle switch selects whether new or old fault conditions are to be displayed. An ADVANCE pushbutton cycles the display to the next fault condition. A FAULT light to the left of the alphanumeric fault display is illuminated whenever a new fault occurs independent of the position of the CURRENT/SUMMARY switch. A flow diagram of the operation is illustrated in Fig. 4-76. A CONTROL display will, upon receipt of a new fault condition contain the same display information as the FAULT display. If the pilot is satisfied with the corrective action taken by the processor, he depresses the ENTER and ADVANCE pushbuttons. If not, depressing the OPTION pushbutton gives the pilot the next option condition, and this is displayed on the CONTROL display. If the pilot elects to select this option, he depresses the ENTER pushbutton. If not, he can cycle to the next option by again depressing the OPTION pushbutton. After having acted on a new fault condition by depressing the ENTER pushbutton, the fault state information will go into the summary file. Subsequent displays of summary fault conditions will indicate the state selected by the pilots previous action. After noting the result of depressing the ENTER pushbutton on the CONTROL and FAULT display the pilot depresses the ADVANCE pushbutton to cycle to the next fault condition. If in the CURRENT mode and no new faults have occurred the display clears.

A RESET ALL pushbutton is available which will initiate a sequence to reset all tripped power controllers by the master unit (MU). Two toggle switches are available to switch the MU and the MUX/DEMUX terminals to their primary or secondary sections, or place them in the normal condition where selection is under control of the MU. Four lights will indicate a failure of a MU and MUX/DEMUX primary or secondary sections. Block switching to primary or secondary MUX/DEMUX sections will be controlled by the toggle switch, individual switching of a particular MUX or DEMUX terminal will be performed by the CONTROL display function.

A typical sequence of operation is illustrated in Fig. 4-77 to 4-80. Assuming the cockpit switch controlling the angle of attack (AOA) transmitter heater has shorted, this information would have been transmitted to the MU from the appropriate MUX terminal. The MU processor can be preprogrammed to place the SSPC

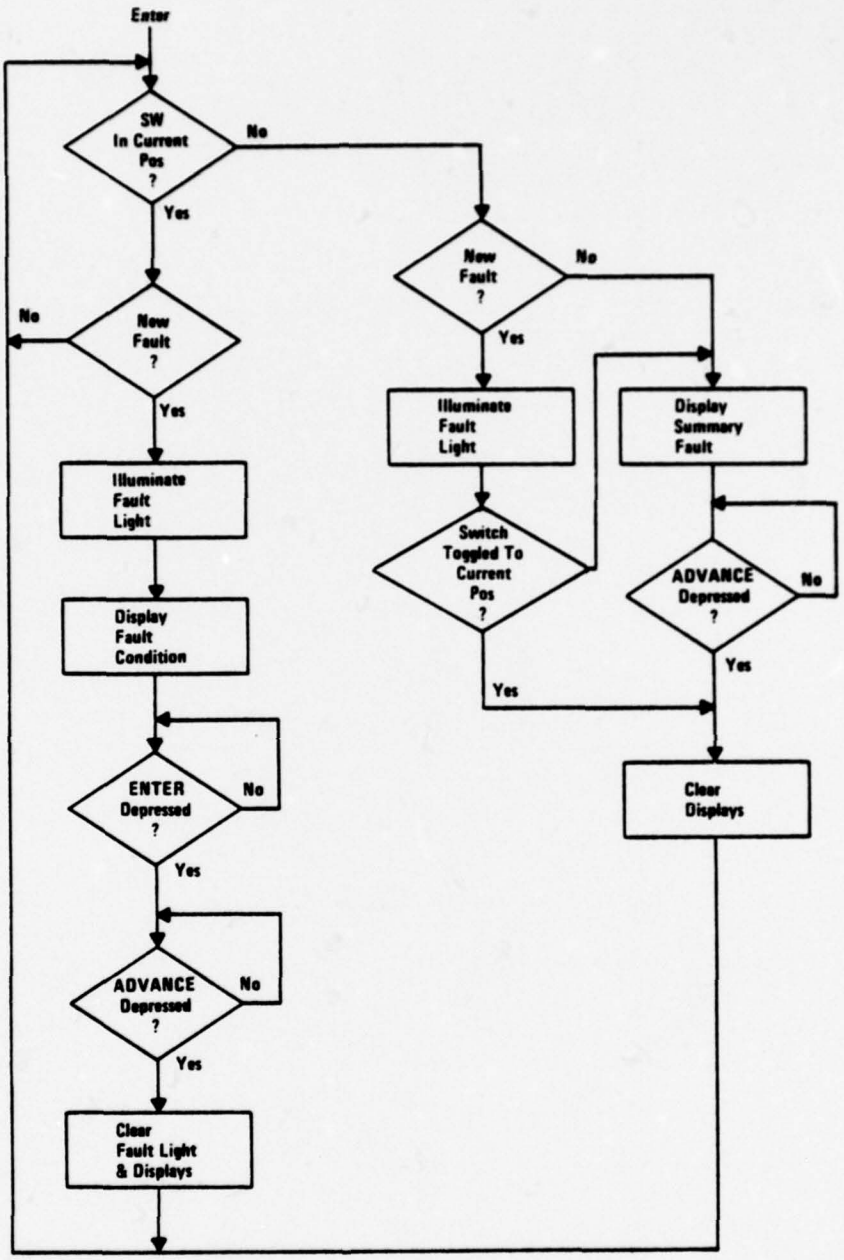


Figure 4-76. Pilots Panel Flow Diagram

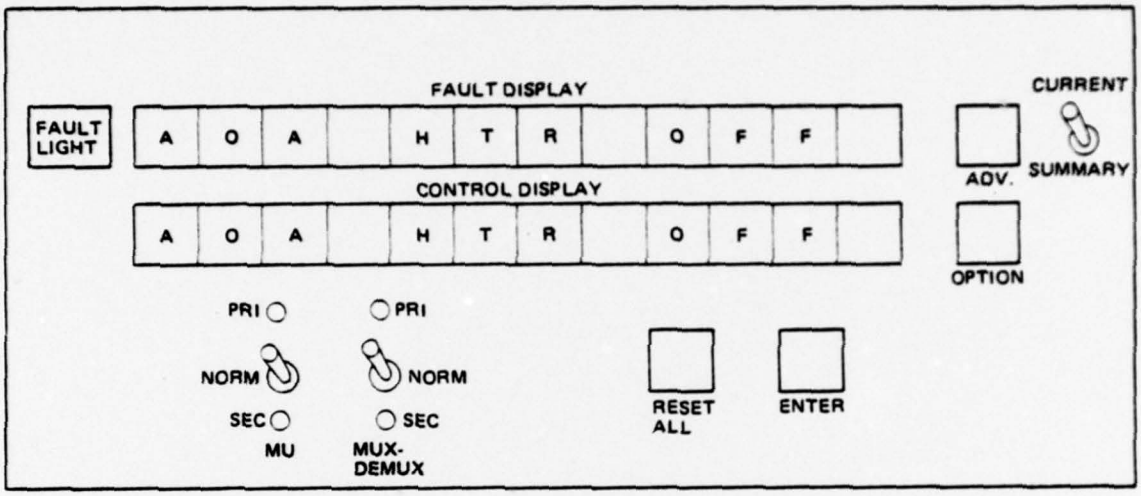


Figure 4-77. Pilots Panel - AOA Heater Failed

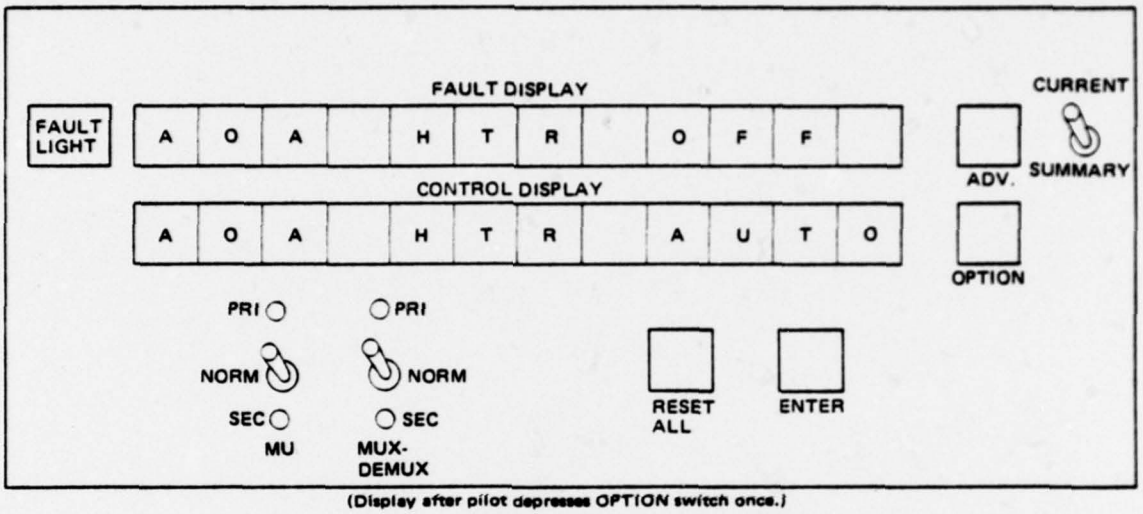
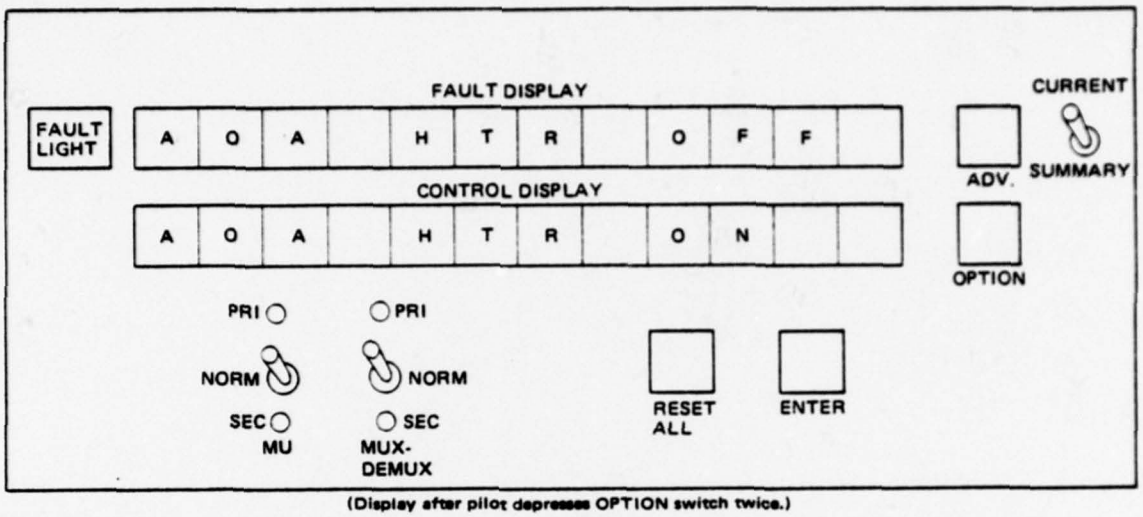
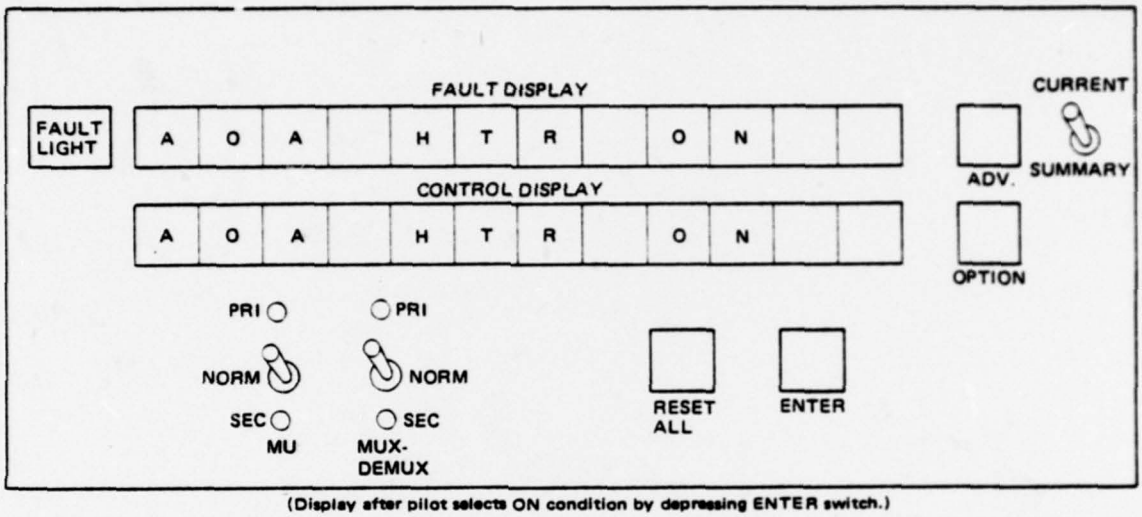


Figure 4-78. Pilots Panel - AOA Heater Auto



(Display after pilot depresses OPTION switch twice.)

Figure 4-79. Pilots Panel - AOA Heater On



(Display after pilot selects ON condition by depressing ENTER switch.)

Figure 4-80. Pilots Panel - AOA Heater Final State

controlling the heater in a safe condition when the transducer fails, but cannot make any further decisions without this switch information. The pilot can obtain the heater state options by depressing the OPTION switch. When the appropriate option is displayed he can select it by depressing the ENTER pushbutton.

4.2.5 SOSTEL/GPMS TIME SHARING

The GPMS/SOSTEL system is examined relative to the F-14 AAES requirements. The baseline dedicated two-channel system is reviewed as a preliminary step to investigating techniques for time sharing of the GPMS channels by the SOSTEL system. The basic consideration is the divergent concepts in a polling contention system (GPMS) and a command response system (SOSTEL). The polling contention technique is implemented about basically "smart" remote terminals (data terminals) and a relatively "dumb" central unit (cable control unit). The command response system is implemented about a basically "smart" central unit (master unit) and relatively "dumb" remote units (multiplexers and demultiplexers). These differences can be resolved by incorporating minor additional capability in the cable control unit.

Two techniques for implementing time sharing and a technique for reducing the channel traffic of the SOSTEL system are investigated. Any of the systems including the baseline dedicated channel system could handle the F-14 SOSTEL traffic with adequate safety margins. However, the four-channel time sharing technique along with the SOSTEL modified polling technique offers the greatest channel usage advantages. The SOSTEL system channel redundancy is doubled while the SOSTEL channel usage is minimized.

4.2.5.1 Baseline Two-Dedicated Channel System

Prior to discussing various techniques for the SOSTEL time sharing of GPMS channels a review of the baseline system is presented. A block diagram of the baseline system is shown in Figure 4-81. The major considerations concerning the operation of the baseline system follow:

The SOSTEL system master unit (MU), multiplexers (MUX), Demultiplexers (DMUX) and crew control and display (CCDP) operate in a command response mode. They use two dedicated channels, i.e., channels 1 and 2 of the data bus cables. They are parallel actively redundant; this implies that the transmissions are accepted over either dedicated channel. The MU communicates with GPMS data terminals (DT's)

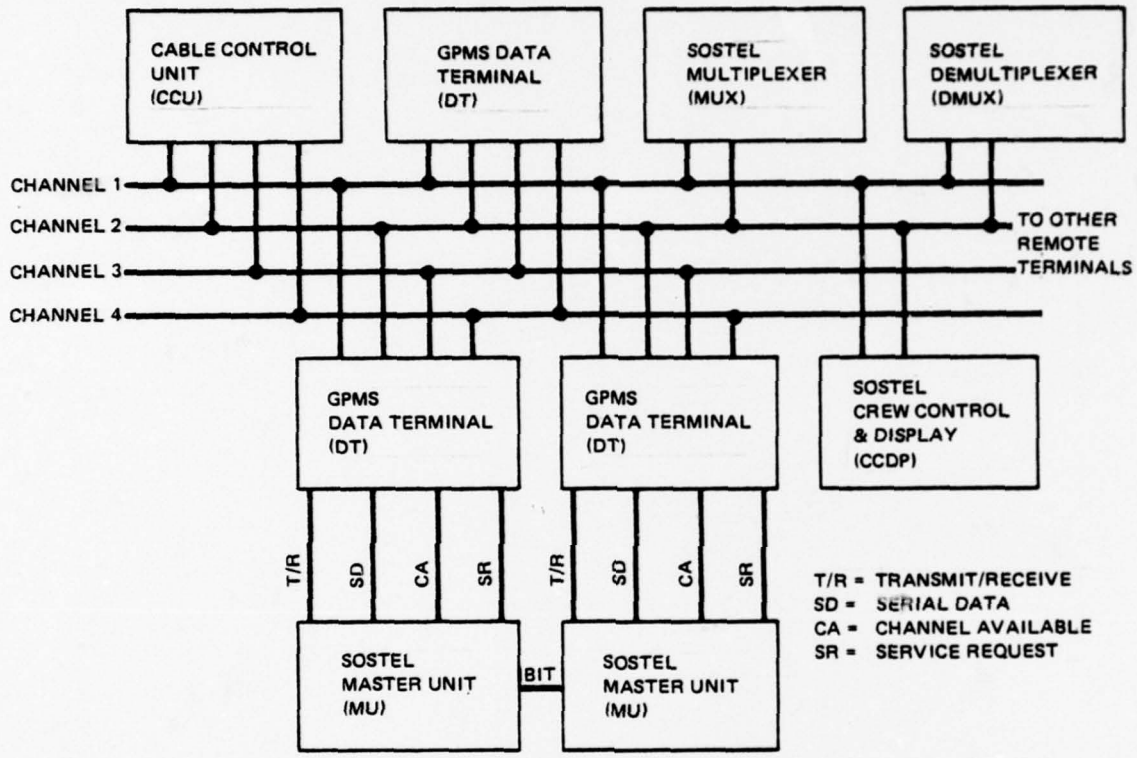


Figure 4-81. SOSTEL/GPMS Baseline, Two-Dedicated Channels System

servicing other subsystems on the remaining two undedicated channels. Because two channels are dedicated to the SOSTEL units the cable control unit (CCU) is inhibited from making an offer on them. It does offer the remaining two-nondedicated channels to the MU, or to the DT's servicing other subsystems which the MU requires communication with at a rate consistant with the 10-msec SOSTEL frame rate. Communication between the MU and DT's servicing other subsystems is in a polling contention mode. This implies that a communication attempt between these units may not be successful if one of the units (MU or DT's) are busy servicing another terminal. The following tabulation outlines the data channel usage by the various elements of the system.

Baseline SOSTEL/GPMS Channel Usage

From/To	CCU	MU	MUX	DMUX	CCDP	DT
CCU	-	3 or 4	-	-	-	3 or 4
MU	3 or 4	-	1 & 2	1 & 2	1 & 1	3 or 4
MUX	-	1 & 2	-	-	-	-
DMUX	-	1 & 2	-	-	-	-
CCDP	-	1 & 2	-	-	-	-
DT	3 or 4	3 or 4	-	-	-	3 or 4

In addition, the baseline concept message structure between the SOSTEL units contain 6-20-bit words; a command, status, and four data words. The CCU to MU or DT's are single 20-bit OFFER words. MU to/from DT's or DT's to/from DT's contain a command, status, and from 1 to 32 data words. These message structures are illustrated in Fig. 4-82.

4.2.5.2 One Dedicated, One Time-Shared Channel

The first technique for time sharing involves the use of one dedicated GPMS channel and one time-shared GPMS channel. The CCU would inhibit offers on the dedicated channel. This channel would be used by the SOSTEL MU to communicate with each of the SOSTEL remote units during normal operation. The time-shared channel would be offered by the CCU to the MU every 10 msec. The CCU requirements to perform this are discussed in the four-channel time sharing section. This

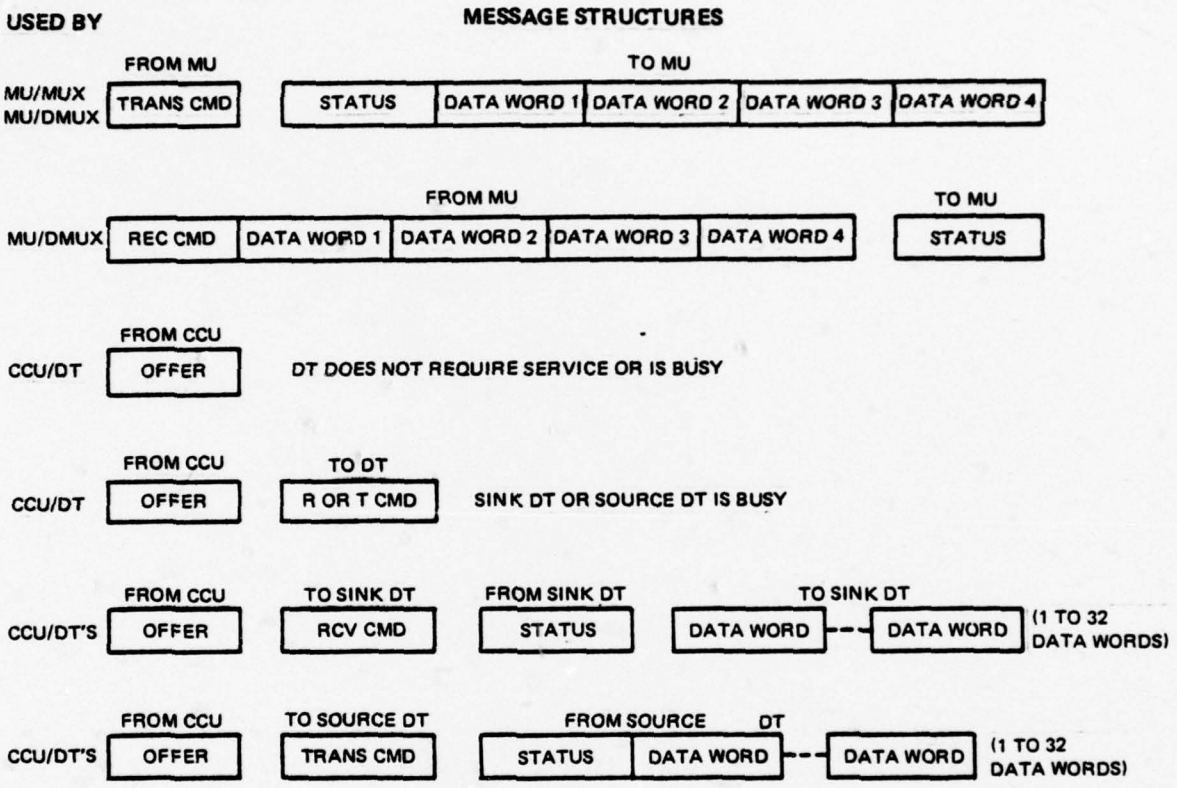


Figure 4-82. SOSTEL/GPMS Message Structures

channel will also be used to provide an alternate path in the event of a failed cable, stub, or electronics in a SOSTEL terminal. It will also be used in conjunction with the remaining two channels to provide a communication path between the SOSTEL MU and DT's servicing other subsystems, and for communication between these DT's.

To allow the SOSTEL system to have its maximum number of units (64), and minimize the impact on the number of GPMS DT's that can time share the line, the addressing scheme must be examined. Since the SOSTEL system has fixed message lengths of four data words, there is no need to transmit message numbers in the SOSTEL command word. These bits can be used to identify the individual SOSTEL terminals. Figure 4-83 and Figure 4-84 illustrate an assignment of the addresses which would accomplish this. The resulting system can handle 32 MUX's, 32 DMUX's, 1 CCDP, 1 MU, and 29 DT's. While this may not be an optimum mix for a particular vehicle, it demonstrates the concept. For example, our baseline F-14 system contains 7 MUX's, 11 DEMUX's, 2 MUX/DEMUX (1 services the CCDP, the other services the PGS system), and 8 GPMS DT's (1 servicing each MU, 6 performing dedicated SOSTEL functions). This is a total of 28 "SOSTEL" terminals. A single address would be assigned to the MU (00000), a single address for all remote SOSTEL terminals (00001), 27 subaddresses are used to distinguish the remote SOSTEL terminals. The remaining 30 addresses would be available for use by the GPMS DT's.

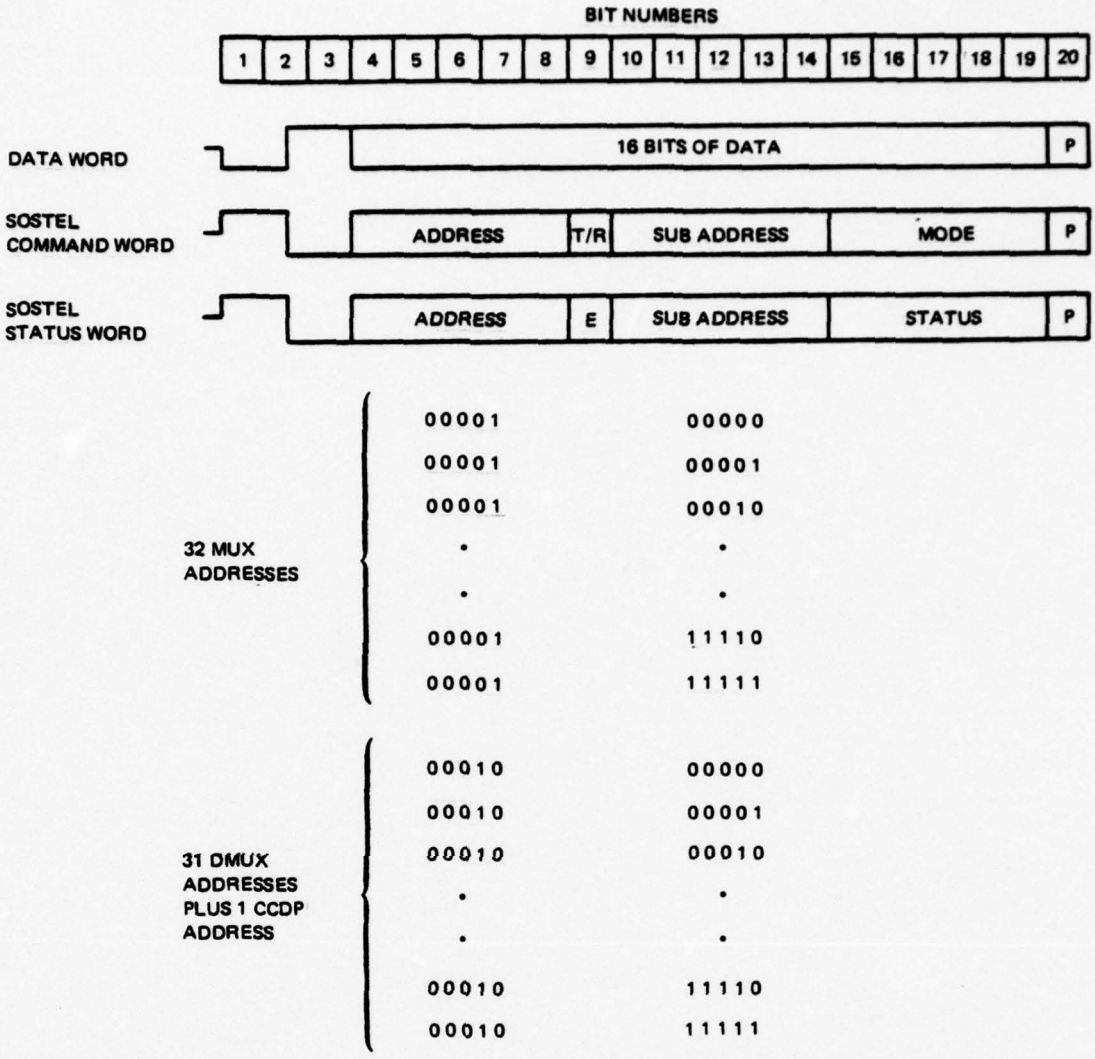
4.2.5.3 Four-Channel Time Sharing

This discussion examines a technique for the time sharing of all GPMS cables by the SOSTEL system. In addition, modifications to the SOSTEL system to increase the available GPMS utilization time of the channels are subsequently described.

Figure 4-85 is a simplified block diagram of a GPMS/SOSTEL system. For the purposes of this discussion the following baseline operation is assumed:

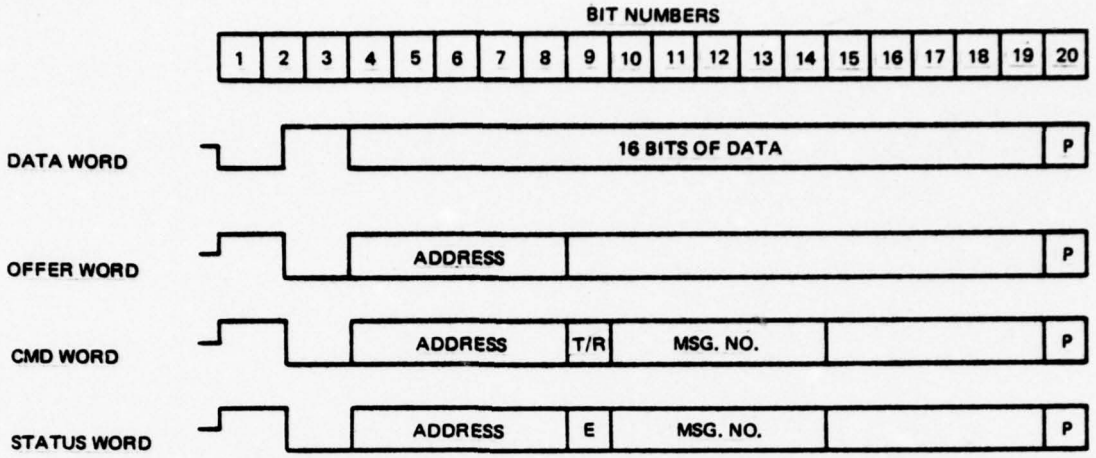
1) The GPMS units (Cable Control Unit (CCU) and the Data Terminals (DT)) operate in a polling mode

2) The SOSTEL Units, MU, MUX, DMUX and CCDP operate in a command response mode



T/R = TRANSMIT/RECEIVE
E = ERROR
P = PARITY

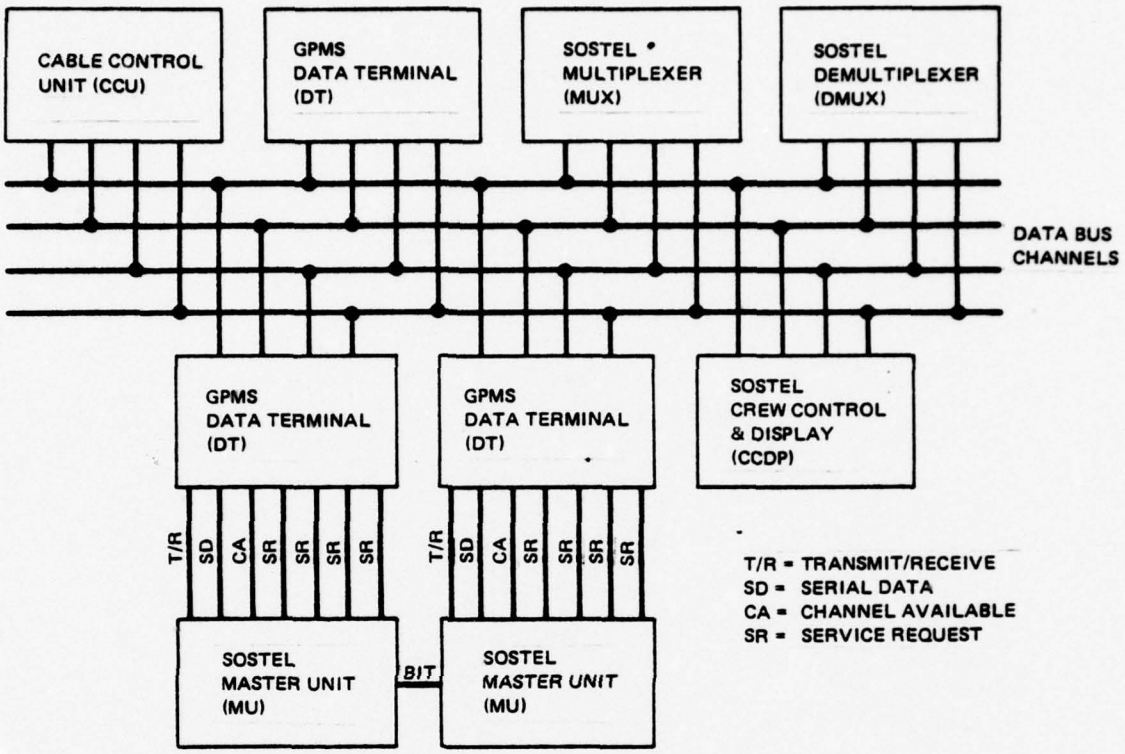
Figure 4-83. SOSTEL Command Response Addressing Scheme



SOSTEL MU	00000	
DT NO. 3	00011	
•	00100	
•	•	
•	•	
•	11110	
DT NO. 31	11111	
1 WORD MSG		00000
•		00001
•		•
•		•
•		11110
32 WORD MSG		11111

T/R = TRANSMIT/RECEIVE
E = ERROR
P = PARITY

Figure 4-84. GPMS Addressing Scheme



SR CODE	MU WILL ACCEPT SERVICE ON:
0000	NO SERVICE REQUIRED
0001	CHAN 1
0010	2
0100	3
1000	4
0011	1 OR 2
0101	1 OR 3
1001	1 OR 4
0110	2 OR 3
1010	2 OR 4
1100	3 OR 4
0111	1 OR 2 OR 3
1011	1 OR 2 OR 4
1101	1 OR 3 OR 4
1110	2 OR 3 OR 4
1111	CHAN 1 OR 2 OR 3 OR 4

Figure 4-85. GPMS/SOSTEL System, Four-Channel Time Sharing

3) The SOSTEL MU is offered the channels in a polling mode by the CCU at a minimum rate consistant with the SOSTEL frame rate (10 msec)

4) The SOSTEL MU communicates with GPMS terminals performing dedicated SOSTEL functions in command response mode. It communicates with GPMS units servicing other subsystems in the polling mode

5) All units have unique addresses with the exception of the GPMS DT's servicing the SOSTEL MU (as will be discussed subsequently). The SOSTEL remote units will have the same address, but will be uniquely identified by the subaddress as previously discussed

6) Each of the MU's are on and actively performing simultaneous processing and storage; however, only one unit will direct SOSTEL message sequences at any given time, and the other MU is in a monitor mode

7) All SOSTEL units are connected to each of the four data bus channels. The technique described is, however, applicable for less than four channels.

Time sharing of GPMS cables by SOSTEL can be implemented in a similar fashion to GPMS, where the CCU offers channels to GPMS data terminals. The data terminals servicing the MU would have identical addresses. The determination of which MU will control the SOSTEL message sequence will be performed by the SOSTEL MU's using self-test programs, hardware BIT between the MU's, and the CCDP switches. The CCU address list should be configured to ensure that the SOSTEL MU is offered each channel every 10 msec. Since a GPMS message can be as long as 700 usec, ignoring gap times (offer, command, status and 32 data words), or as short as 80 usec (offer, command, status and 1 data word) repetition in the normal polling sense of the SOSTEL MU address in the address list is not adequate. The CCU will be required to have a 10-msec timer associated with each channel, which when set, will force the SOSTEL MU address to the top of the address list. When the timer is set the CCU will offer the idle channel to the SOSTEL MU. The timer will be reset after the offered channel goes idle. Thus, the timer is reset if the SOSTEL MU requires no service or at the end of a SOSTEL message sequence on this

channel. If the SOSTEL MU is using one cable and a second, third, or fourth SOSTEL cable timer becomes set, the CCU will continue offering these channels to GPMS DT's until the channel the SOSTEL MU is presently using becomes idle. It will then offer the next idle channel which has its timer set to the MU. It will continue this sequence until all channel timers are reset.

Figure 4-86 is a flow diagram of the CCU operation for any one of the channels. The worst case condition for this operation is when SOSTEL requires use of all four cables during one frame time. Having accepted one cable, and if the other cable timers become set while the SOSTEL MU is busy, then, when the SOSTEL MU has completed its transmission on the cable it was using, it may have to wait one GPMS DT message or a maximum of 700 usec before being offered the next channel. Similarly this can occur on the remaining two cables, thus the maximum wait time is 2100 usec before all cables can be accessed. For the F-14 SOSTEL system described subsequently the bus is only used at most for 3600 usec using any single cable. The additional wait time if all four cables are required still allows a 10 msec frame rate with adequate safety margin.

The SOSTEL MU must maintain a record of the previous message successes/failures to the remote SOSTEL units. It uses this information to determine which channels can be used for messages to each of the remote units. The MU therefore must alert the DT servicing it as to which channels it requires service on. Four service request lines between the MU and the DT servicing it will be used to alert the DT as to which channels the MU will accept to service the remote terminals. These four service request lines can be used to encode all 16 combinations of desired channels.

4.2.5.4 SOSTEL Modified Polling Technique

The F-14 SOSTEL system as presently configured interfaces with 11 DMUX, 7 MUX, 8 GPMS, 2 MUX/DMUX terminals. The bus utilization time is calculated to be 3.60 msec, or 36.0% of the 10-msec frame rate. This utilization is based on 6-word, 20-bit message to/from each terminal in a 10-msec frame and ignores gap times

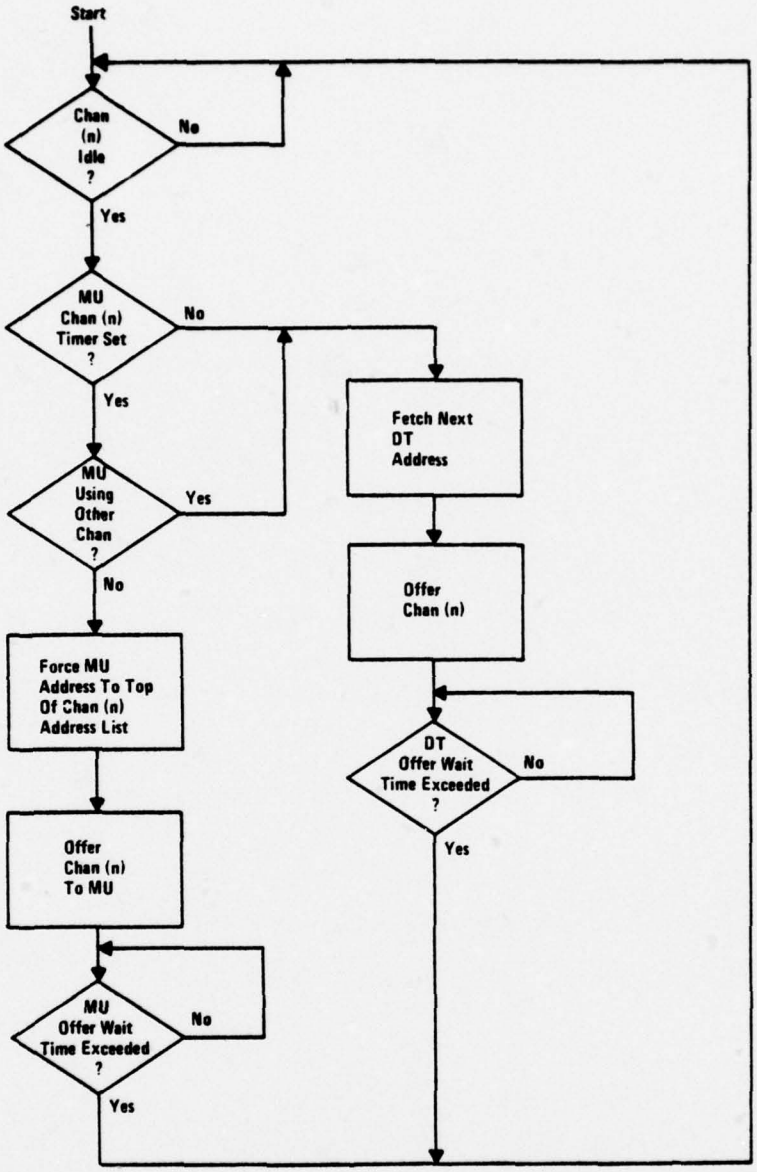


Figure 4-86. CCU Flow for SOSTEL Time Sharing

DEMUX:	11 x 6 x 20 = 1320 usec
MUX:	7 x 6 x 20 = 840 usec
GPMS DT:	8 x 6 x 20 = 960 usec
MUX/DMUX:	2 x 2 x 6 x 20 = 480 usec
	3600 usec

The foregoing indicates that the SOSTEL channels have adequate spare time to make time sharing by GPMS data terminals attractive. In addition, if the SOSTEL system were modified to transmit information only when data changes occurred (utilizing modified polling as well as command response) the bus utilization time would be reduced significantly. This concept involves modification to the SOSTEL system such that:

- The SOSTEL MU transmits data to DMUX's only when it has new data for that DMUX. This could also involve periodic updates at rates less than every 10 msec
- The MUX's and DMUX's would transmit data to the MU only a) upon command; b) when flags have been set.

Figure 4-87 illustrates the response of a MUX or DMUX to a command word and as a function of its flags. The system would be configured such that commands directions would have priority over flag initiated actions, the DMUX trip flag would have priority over the fault flag, and MUX fault flag would have priority over MUX ON/OFF flag. SOSTEL bus utilization would be dependent upon the rate at which information changes occur rather than fixed. The minimum utilization of 1280 usec (command word and status word only to each terminal) is required to ensure the operational integrity of the bus and terminals.

The impact of the above concept on the design of the multiplexer and demultiplexer is minimal. It involves the recognition of an additional bit along with the transmit/receive bit which would be used to determine whether the units have been directed to transmit data and what data is to be transmitted. In addition, these units would be required to respond with a status word only if not commanded to transmit

MASTER UNIT COMMAND WORD						REMOTE TERMINAL RESPONSE
		MUX STATUS BITS		MUX FLAGS		
T/R	ON-OFF/ FAULT	ON/OFF	FAULT	ON/OFF	FAULT	
1	0	1	0	X	X	MUX TRANSMITS STATUS AND ON/OFF DATA
1	1	0	1	X	X	MUX TRANSMITS STATUS AND FAULT DATA
0	X	0	0	0	0	MUX TRANSMITS STATUS ONLY
0	X	1	0	1	0	MUX TRANSMITS STATUS AND ON/OFF DATA
0	X	0	1	X	1	MUX TRANSMITS STATUS AND FAULT DATA

		DEMUX STATUS BITS		DEMUX FLAGS		
T/R	FAULT/ TRIP	FAULT	TRIP	FAULT	TRIP	
0	0	0	0	X	X	DMUX RECEIVES ON/OFF DATA, TRANSMITS STATUS
1	0	1	0	X	X	DMUX TRANSMITS STATUS AND FAULT DATA
1	1	0	1	X	X	DMUX TRANSMITS STATUS AND TRIP DATA
0	1	0	0	0	0	DMUX TRANSMITS STATUS ONLY
0	1	1	0	1	0	DMUX TRANSMITS STATUS AND FAULT DATA
0	1	0	1	X	1	DMUX TRANSMITS STATUS AND TRIP DATA

X = DON'T CARE

Figure 4-87. SOSTEL Modified Polling Response

data and no flags are set. This involves modification to the flag priority circuitry. Grumman implemented this concept in a breadboard multiplexer and demultiplexer. The changes involved a few additional gates and an additional flip/flop when implemented in the non-programmable breadboard system.

The impact on the MU process computational load and memory are a function of the level at which the concept is implemented. In general, it involves solving the Boolean equations and outputting new data to the DEMUX's only when new MUX or DEMUX data are received. The concept can be implemented based on an input bit, word, single terminal, or all terminals, level. The minimum penalty to the processor occurs when, if all terminals respond with a status word only (indicating they have no new data to transmit), then the processor will not be required to solve its complement of Boolean equations. If any terminal transmits data, then all equations must be solved.

The change involves a conditional jump to set a flag if any remote terminal responds with more than a status word. This routine would be part of the subroutine which examines the status word flag bits to determine whether the information should be stored in input, fault, or trip storage. To establish the advantages this approach would offer it is necessary to determine the expected changes in MUX data per frame. It is assumed that fault and trip changes will be negligible.

Analysis of the first 200 transducers (001 to 200) tabulated was performed to arrive at a realistic rate at which these input terms to the Boolean equations would change state. On hundred and thirty-eight of these devices are cockpit switches, remote switches, or discretes which would change only a few times per flight during normal operation. The remaining sixty-two devices are remote switches or discretes which were conservatively estimated to change at a rate of 0.1 Hz or once every five seconds. These estimated rates and the number of devices in each classification is as follows:

	0.1 CPS	1 CPF	2 CPF	4 CPF	10 CPF	20 CPF
No. of Transducers	62	29	83	11	13	2

NOTE: CPF = Cycles Per Flight

A nominal 10,000-second (2.77 hour) "flight" was assumed. "Flight" time was assumed to be from aircraft power up to power down. The number of transitions (ON - OFF) per flight is 125×10^3. This equates to an average of 12.5 transitions per second or 0.125 transitions per SOSTEL frame (10 msec). For a SOSTEL system containing 10 MUX terminals or 640 transducers the number of transitions per frame is prorated to be an average of 0.4 transitions per frame.

In addition, the number of equations each of the first 200 transducers were used in was derived. Some transducers are input terms to only one equation; others such as weight on wheels, affect as many as 81 equations. On the average, each transducer affects four equations. Thus, if this technique were to be implemented on an input bit basis, i.e., (solve only those equations associated with the changed bit), a look-up table would be required associating each input on the average with four equations.

Utilizing the approach where all equations would be solved if any remote terminal reported new data, the Boolean equations must be solved only every two and one-half frames. The data bus traffic is reduced to (0.4 x 3600 = 1440 usec). With this approach time sharing of the SOSTEL data bus channels by GPMS terminals becomes much more attractive since the SOSTEL bus utilization can be reduced to less than 15%, thus allowing more time for GPMS terminal use.

4.2.6 MULTIPLEXER, DEMULTIPLEXER, DATA BUS, AND TRANSDUCERS

4.2.6.1 In-House AD MUX and DEMUX Design

The requirements of the SOSTEL Multiplexer (MUX) and Demultiplexer (DEMUX) terminals were analyzed and single thread (no block redundancy) units utilizing MSI and LSI components were designed during a previous in-house Advance Development effort. The designs are based upon use of a standard interface unit (SIU) capable of providing the required interface to the data bus and the user I/O. A remote input terminal (RIT) was developed to provide the MUX I/O function. A remote output terminal (ROT) was developed to provide the DEMUX I/O function. Thus, as conceived, an SIU plus a RIT constitutes a SOSTEL MUX terminal. A SIU plus a ROT constitutes a SOSTEL DEMUX. A complete description of the operation of these elements is given in the Grumman Advanced Development Report ADR-09-03-76.1, titled "The Design of a Solid State Electric Data Bus System," dated January 1976. A summary description of the essential functional elements follows.

The SIU was conceived as a general-purpose data bus and user I/O buffer. It is capable of receiving information from the data bus, decoding the information, and transferring it in suitable form along with control signals to the user I/O. In addition, it is capable of receiving user I/O information and transmitting this data properly encoded on the data bus. The significant functional requirements of the SIU are:

- Timing and control
- Invalid Bi-ϕ detection and encoding
- Bi-ϕ decoding and encoding
- Parity detection and encoding
- Address detection and encoding
- Serial-to-parallel and parallel-to-serial conversion
- Word formating
- Temporary buffer storage.

A block diagram of the SIU is illustrated in Fig. 4-88 a flow diagram of the unit is shown in Fig. 4-89. The RIT was designed to provide the user I/O functions of the SOSTEL MUX. Figure 4-90 is a block diagram of this element; Fig. 4-91 is an operational flow diagram. In the SOSTEL system the RIT provides the interface to the solid state transducers. The principle functions of the RIT is to sample, encode, compare, and temporily store the state of up to 64 solid state transducers. It samples the transducers by strobing a 10 ma current source through the analog multiplexer and detecting the resultant voltage. This information (On/Off, Faulted) is stored in two 64-bit storage registers. Data which does not compare with previously sampled data causes flags to be set indicating a data change has occurred. BIT test is included which simulates an input transducer and confirms correct system operation. Control logic controls this operation and the response of the system to commands from the SIU.

The operation of the ROT is similar to that of the RIT. Figure 4-92 is a block diagram of the ROT; Fig. 4-93 is a logic flow diagram. The addition of 64 storage stages, and 64 10-ma current drivers is required to provide output control for the solid state power controllers (SSPC). These output control lines are sampled periodically to identify the state of the SSPC's (Tripped, Faulted). This information is stored in its respective 64-stage register. Previously stored information (from the previous sample) is compared with the presently sampled data and will cause the appropriate flag to be set if a change in data has occurred. A simulated controller interface is provided on channel 64. It provides BIT information and can be commanded to simulate Trip or Fault conditions. A common switched 10-ma current driver is provided to generate sample current for those channels which are OFF.

4.2.6.2 "Smart" Terminal MUX and DEMUX

An alternate approach to the previously described MUX and DEMUX designs is illustrated in Fig. 4-94. In this design, the terminals are configured about a microprocessor. Figure 4-95 is a photograph of the layout of the Intel 3000 microprocessor chip set for this application. The use of a microprocessor is desirable because it

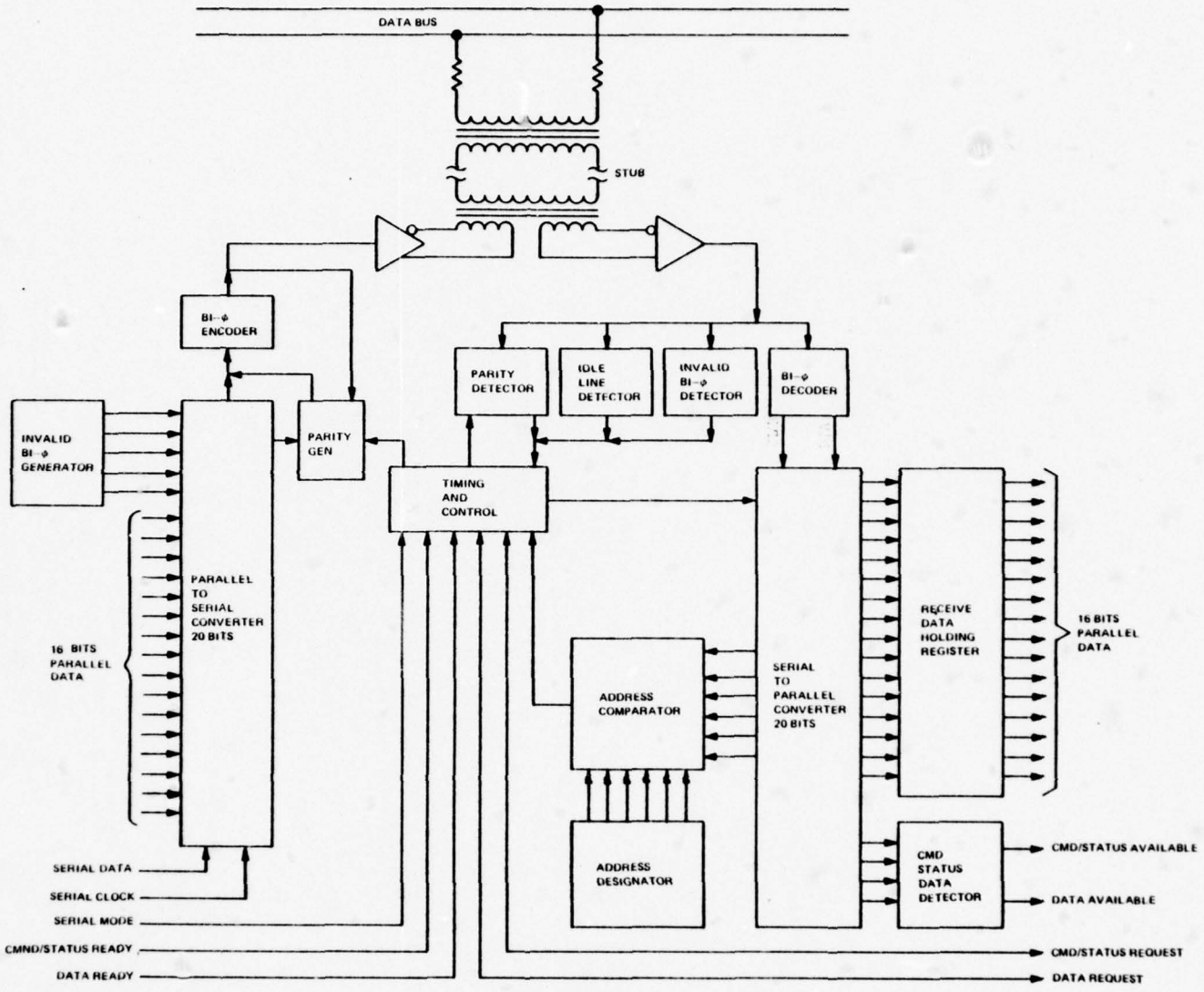


Figure 4-88 Standard Interface Unit

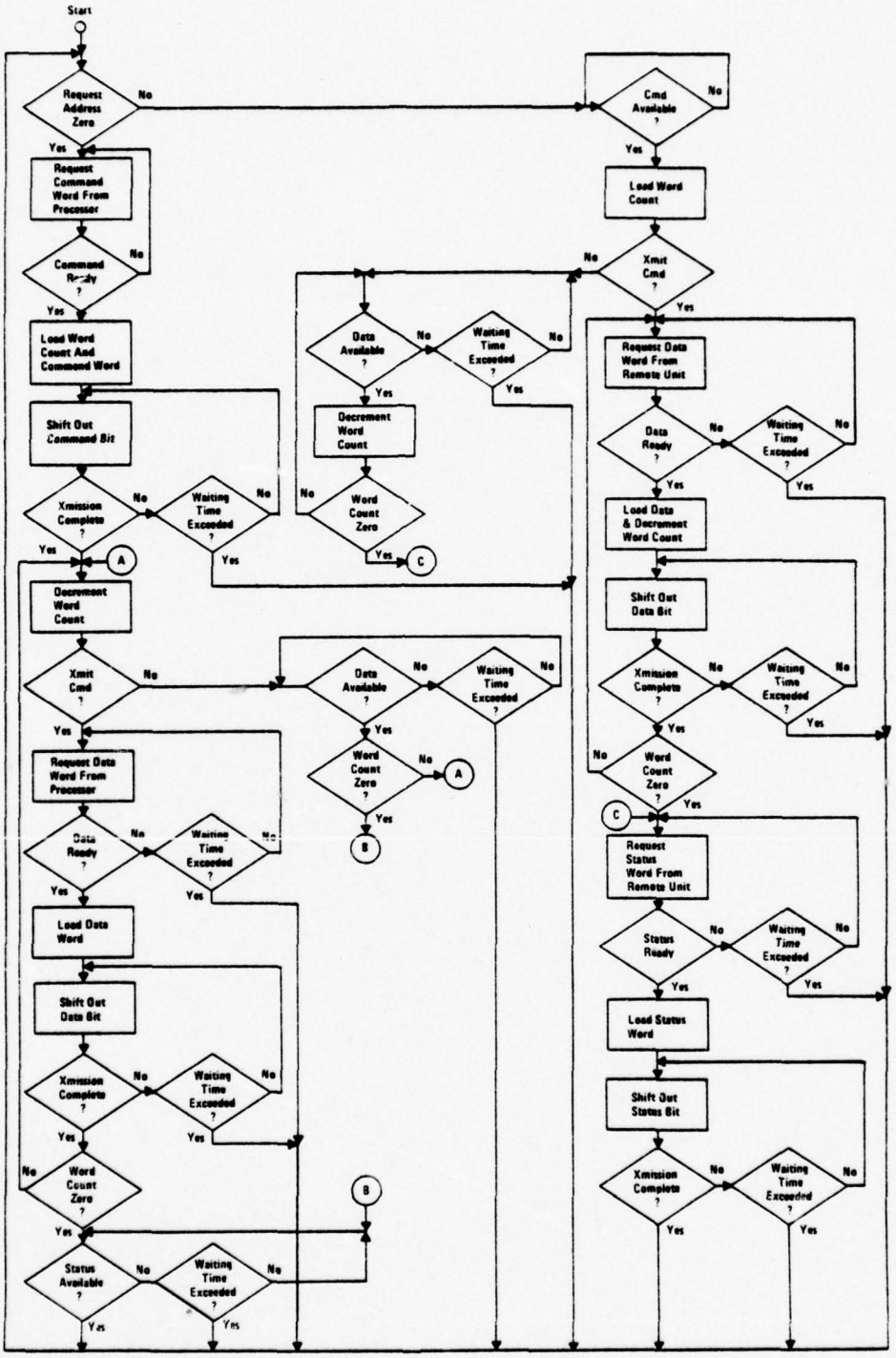


Figure 4-89. SIU Functional Flow Diagram

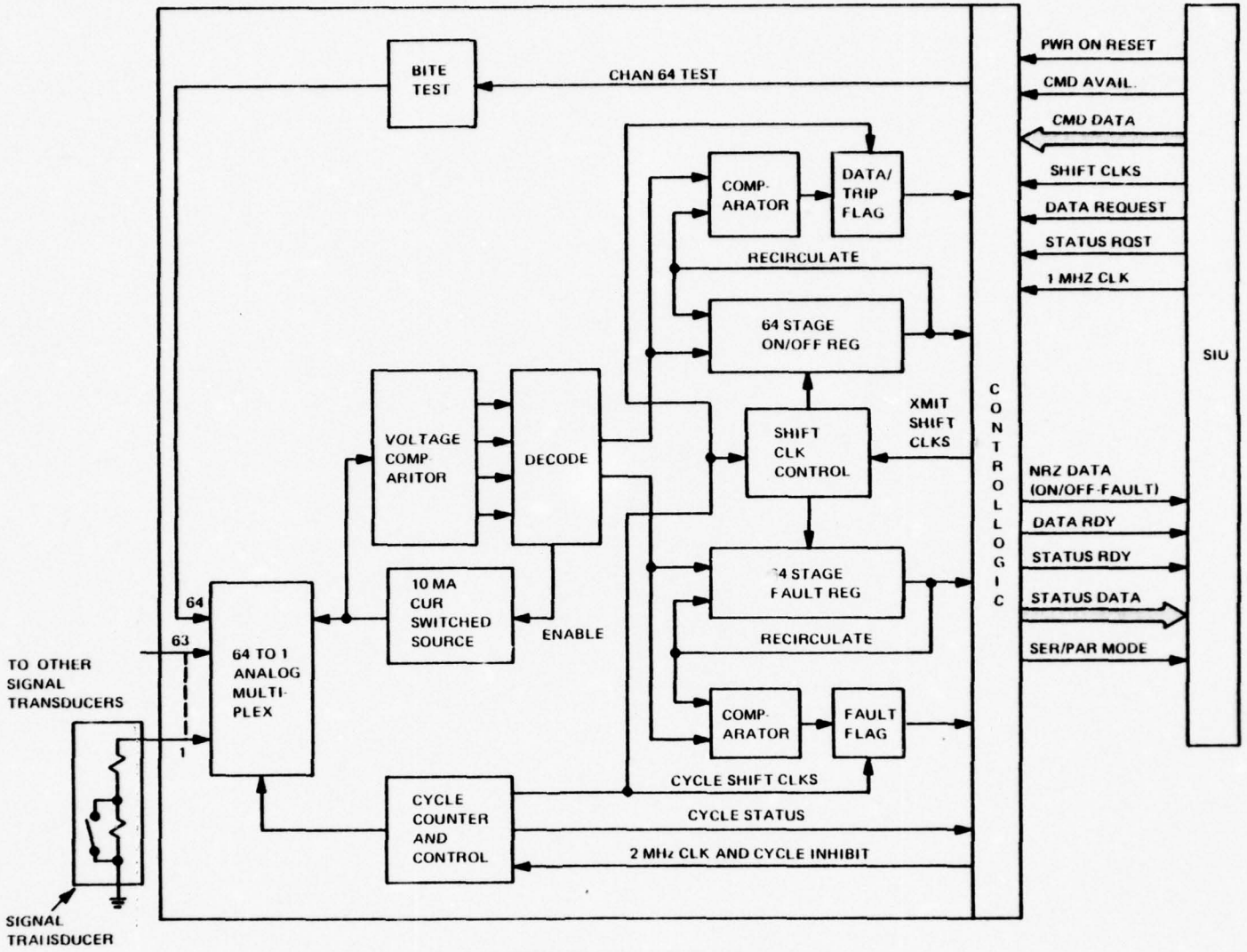


Figure 4-90 Remote Input Terminal

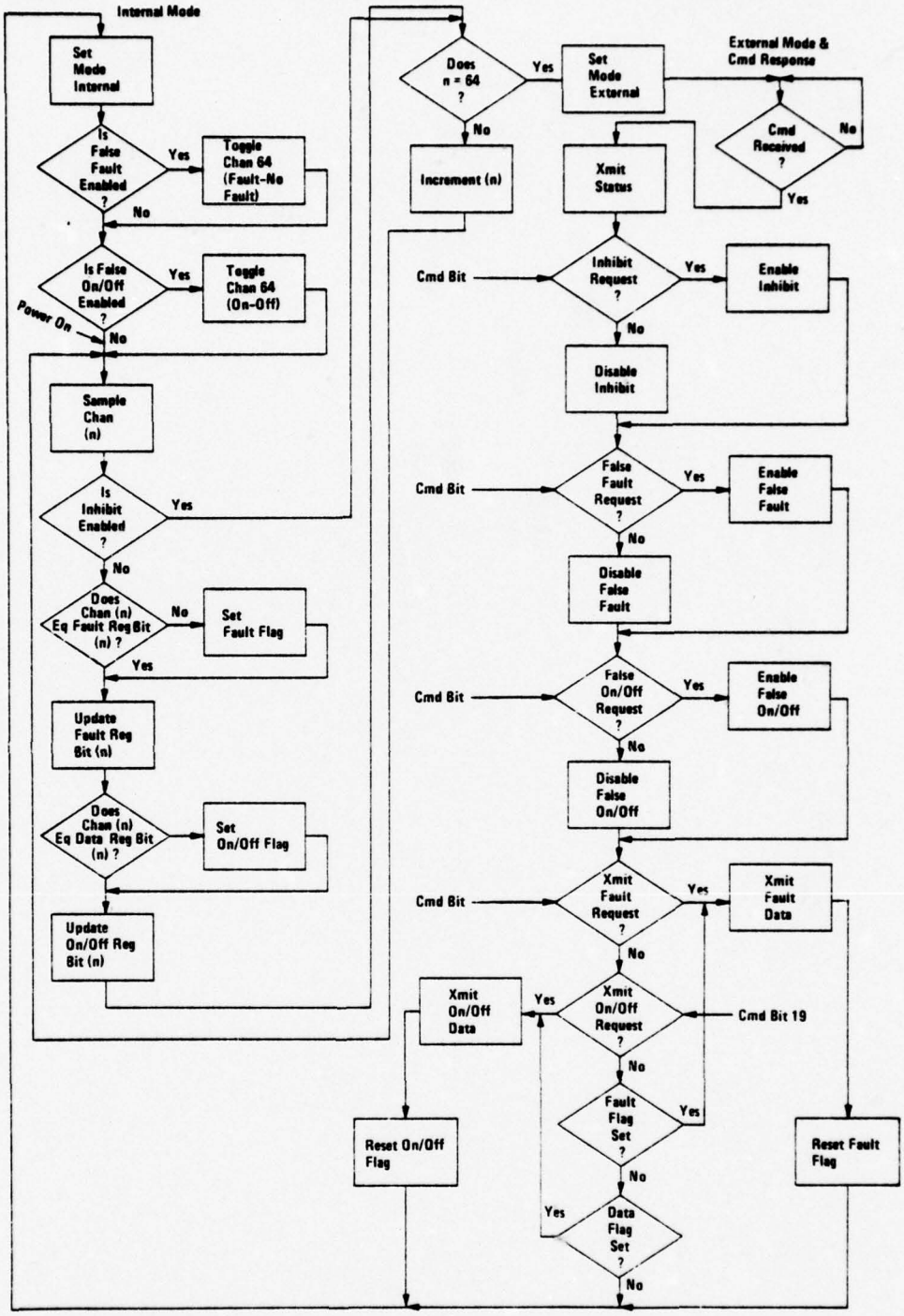


Figure 4-91. RIT Flow Diagram

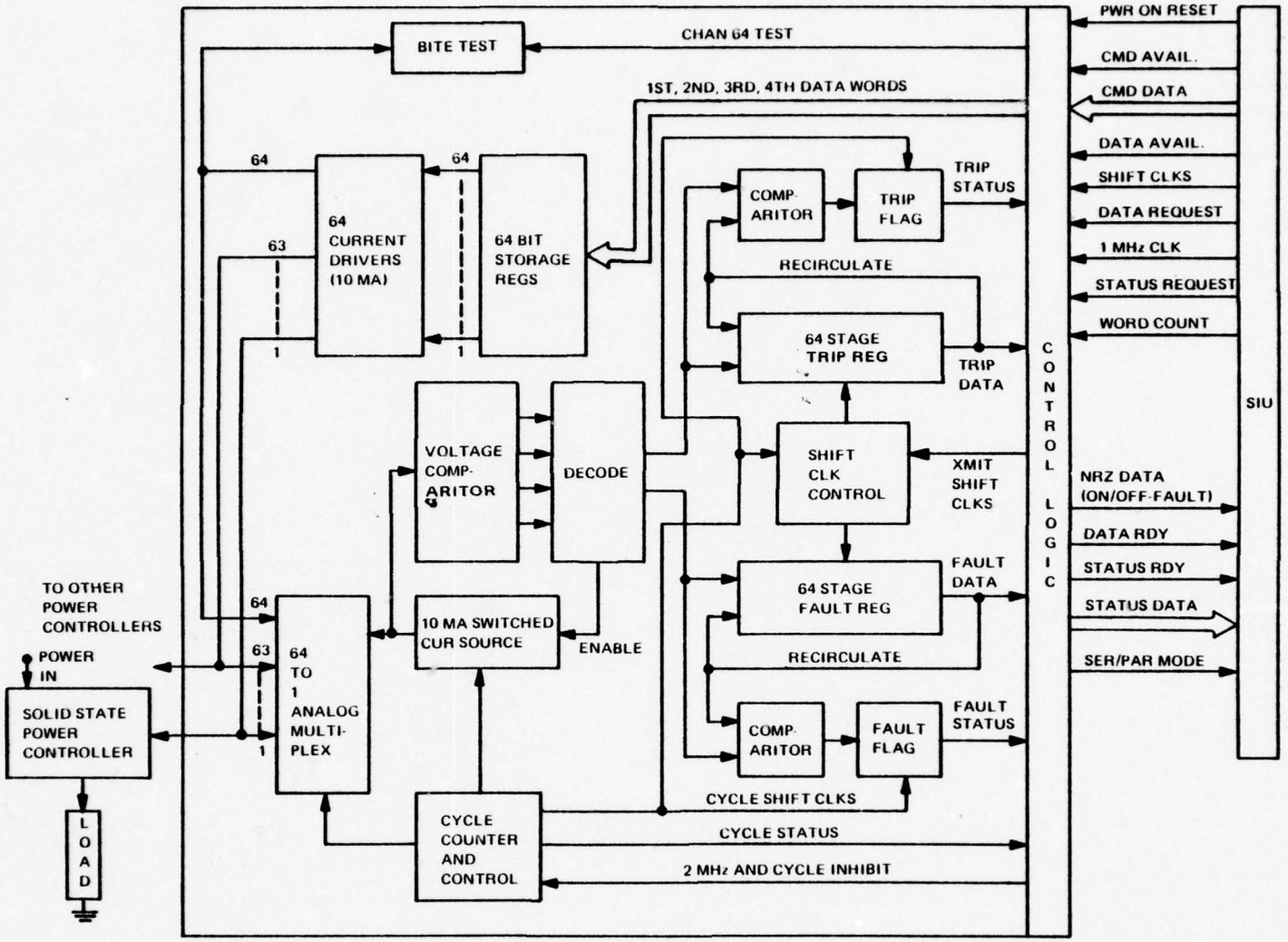


Figure 4-92. Remote Output Terminal

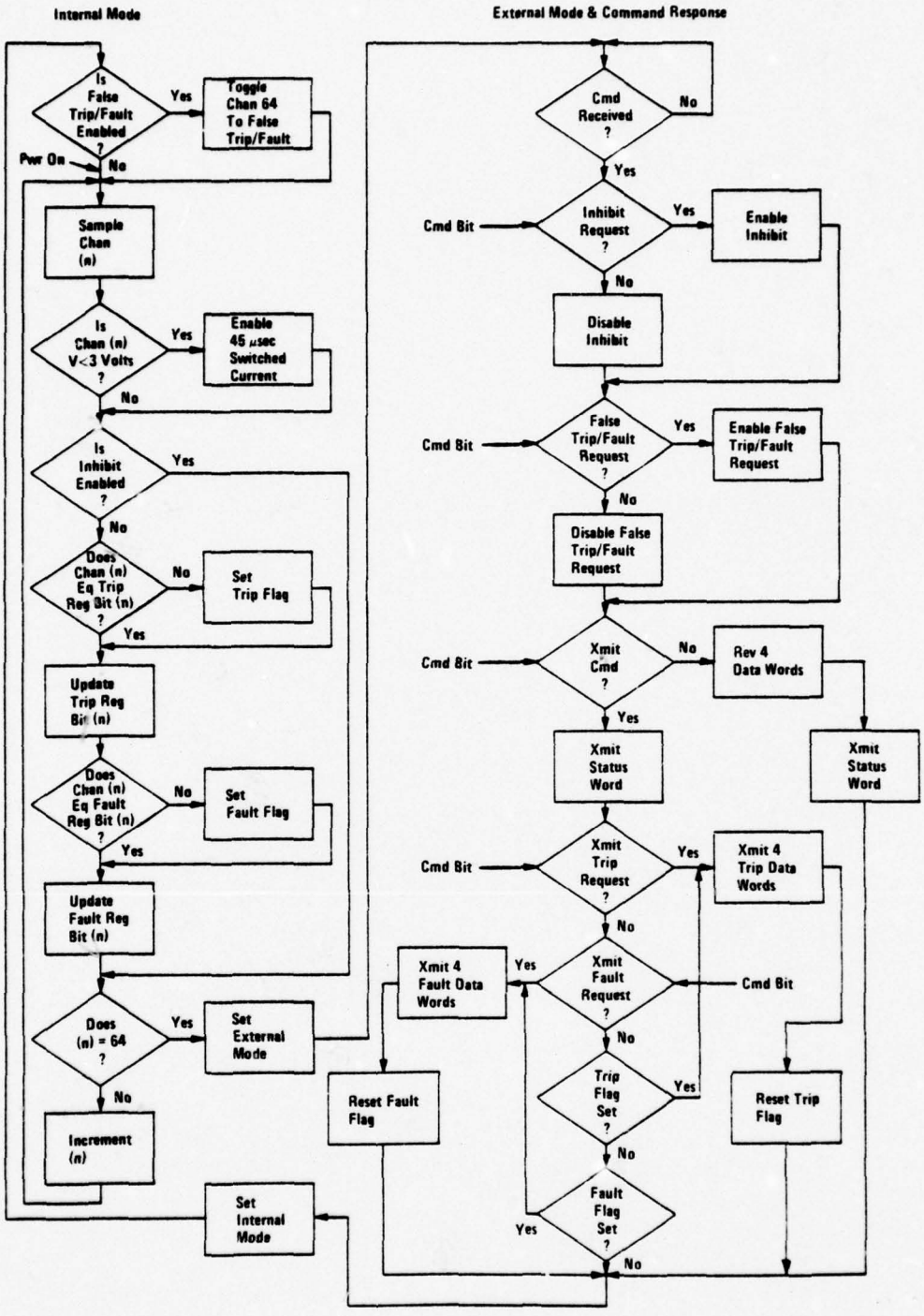


Figure 4-93. ROT Flow Diagram

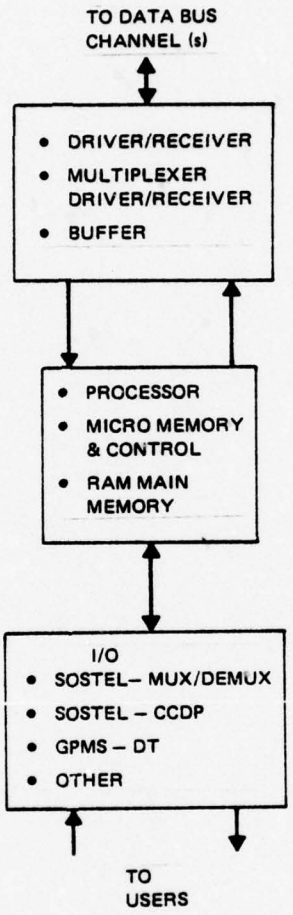


Figure 4-94. Microprocessor Terminal

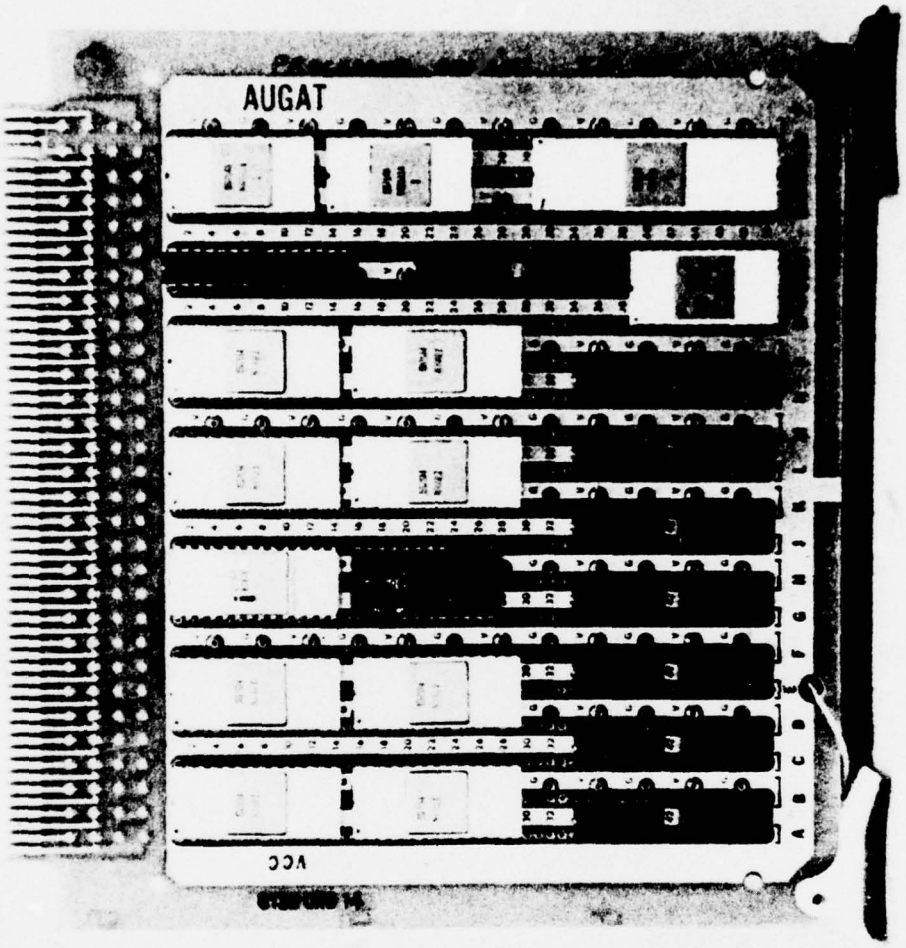


Figure 4-95. Microprocessor Card

allows increased flexibility, decreases the burden on central processors, provides a standard terminal design easily alterable as to function by software, and reduces cost. Its application is intended to provide a common terminal design for SOSTEL, GPMS and other systems which are compatible with MIL-STD-1553A requirements. The user I/O would be configured to the requirements of the user. A terminal would consist of the following functional blocks, and perform the associated functions:

- Redundant Data Bus Line Driver/Receiver (see Fig. 4-96)
  - Data bus coupling and isolation
  - Voltage level conditioning
  - Rise and fall time adjust
  - Signal band pass filtering
- Multiplexer Driver/Receiver (MDR) and MDR Buffer (see Fig. 4-97)
  - Busy/idle detection
  - Sync and sync polarity detection
  - Sync generation
  - BIT and word detection and counting
  - NRZ conversion
  - B1-Phase generation
  - Serial/parallel - parallel/serial conversion
  - Receive and transmit controls
- Microprocessor (see Fig. 4-98)
  - Command decoding
  - Status word generation
  - Data word formating
  - Terminal mode control
  - Data comparison and flags
  - User I/O processing
  - Data compression

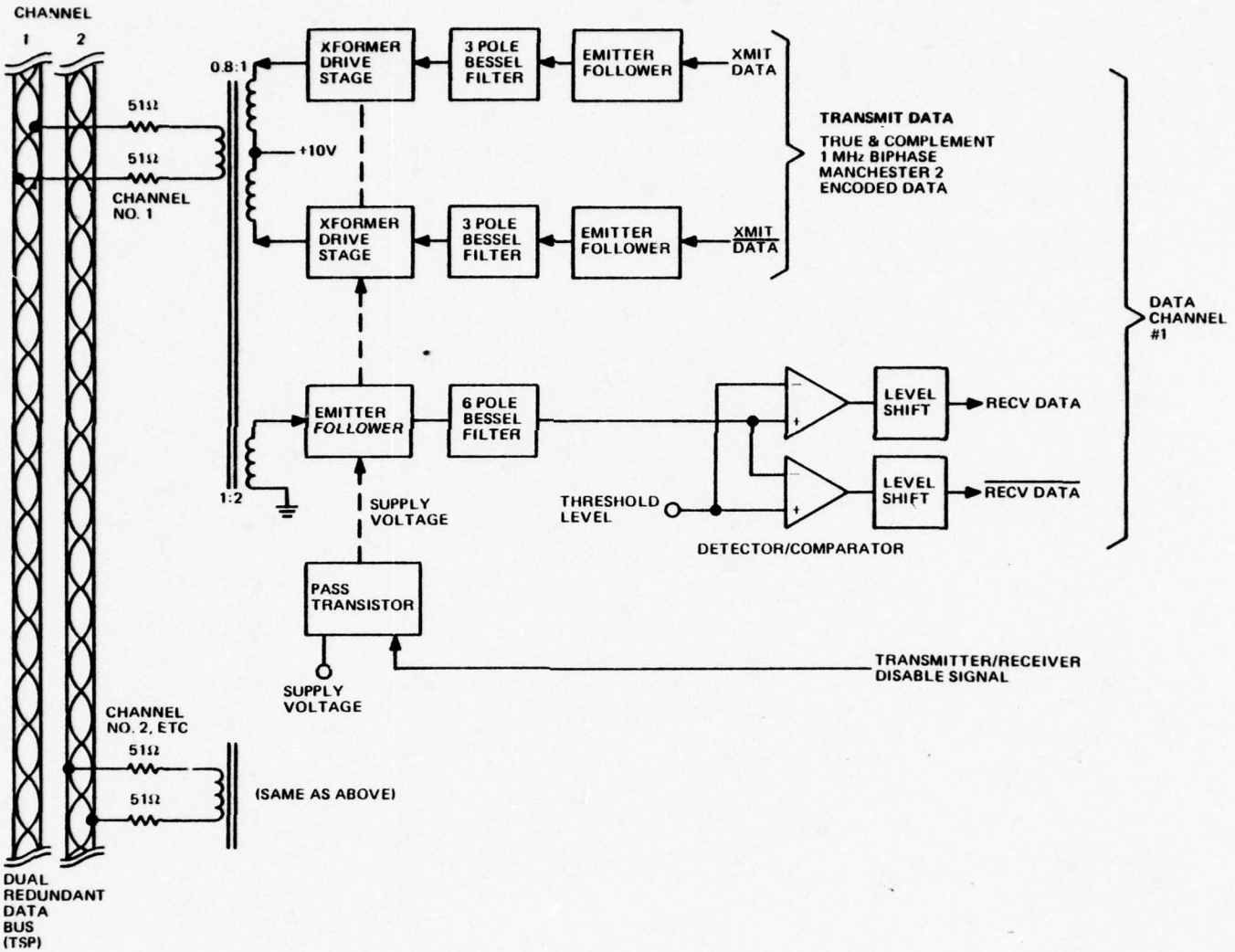


Figure 4-96. Dual Redundant Data Bus Line Driver/Receiver

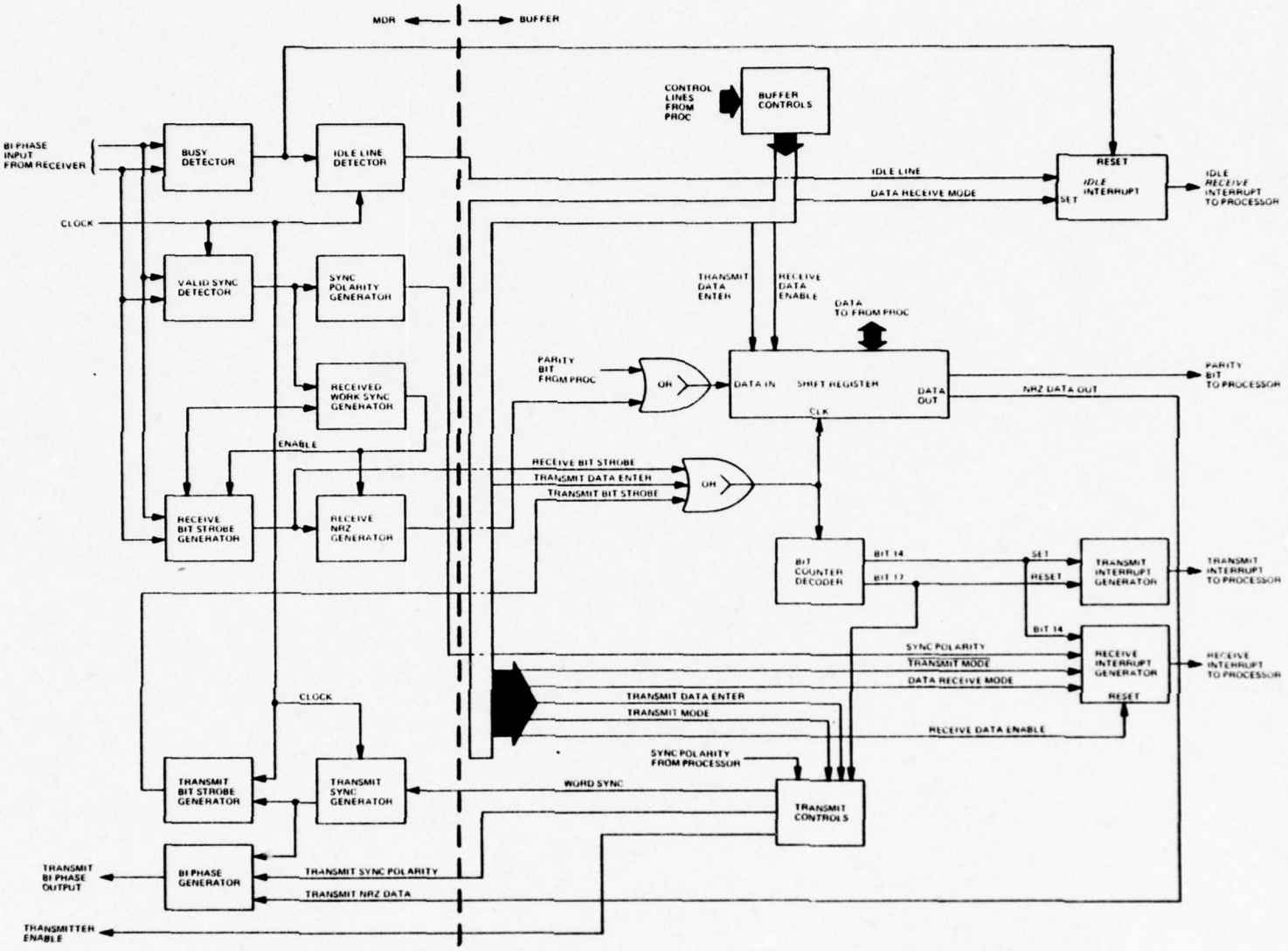


Figure 4-97 Multiplexed Driver/Receiver (MDR) and MDR Buffer

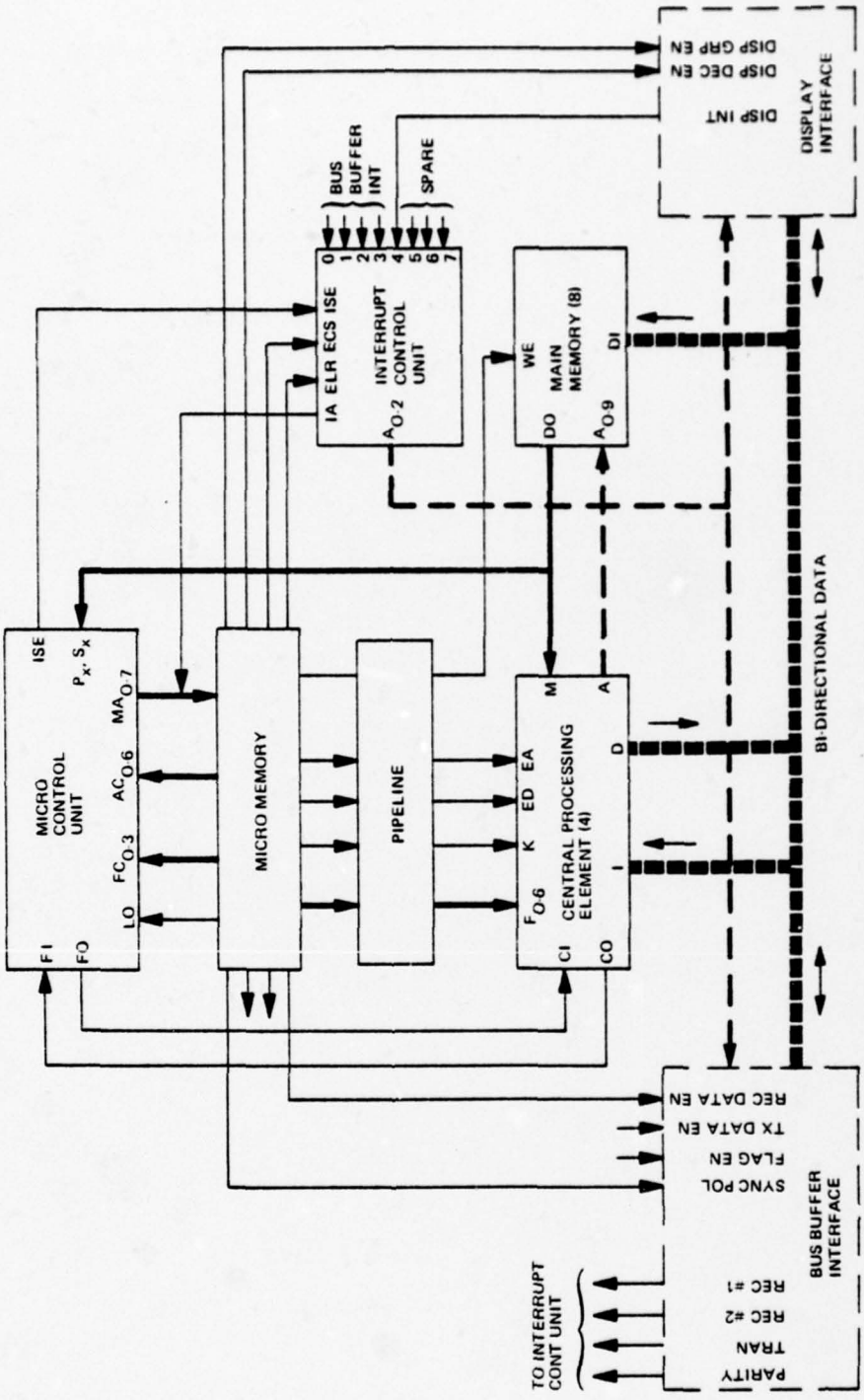


Figure 4-98. Microprocessor Implementation for CCDP

- I/O - SOSTEL Multiplexer and Demultiplexer Functions (see Fig. 4-99)
  - Sampling and encoding
  - Current drivers
  - Buffer storage
  - BIT.

4.2.6.3 Data Bus

The data bus provides the transmission medium for communication between the various SOSTEL control-group and GPMS equipments. Information is transmitted via the buses at 1 MBPS using time division multiplexing, half-duplex, Manchester II level coding, biphase-level modulation techniques. Twisted shielded-pair cables are adequate media for a 1-to-3 MBPS digital system for cable runs of 300 ft. Coaxial cable can extend the transmission bandwidth to approximately 10 MBPS. Fiber optics technology is available for systems requiring up to 200 MHz bandwidth on up to 300 meters of cable. Fiber optics offers significant advantages over metallic cable systems in that it is not susceptible to, and does not generate, electrical or magnetic noise; it can be electrically isolated; it can operate at higher temperatures; it eliminates electrical hazards, and it has much greater bandwidth. For a point-to-point, full-duplex system where these characteristics are required, it is a logical choice. However, the primary objection to its use on the SOSTEL system involves the difficulty and attenuation losses associated with coupling to the fiber optic data bus and the cumulative losses caused by bulkhead interfaces on an aircraft when a half-duplex, multi-ported data bus configuration is required. The application of fiber optic technology have been the subject of a number of studies and tests (ALOFT-IBM, Optical Cable Communications Study - Harris). The basic design of a data bus system such as SOSTEL would not be significantly altered if future developments justify the replacement of the TSP wiring and transformer coupling with fiber optic cabling and optical couplers.

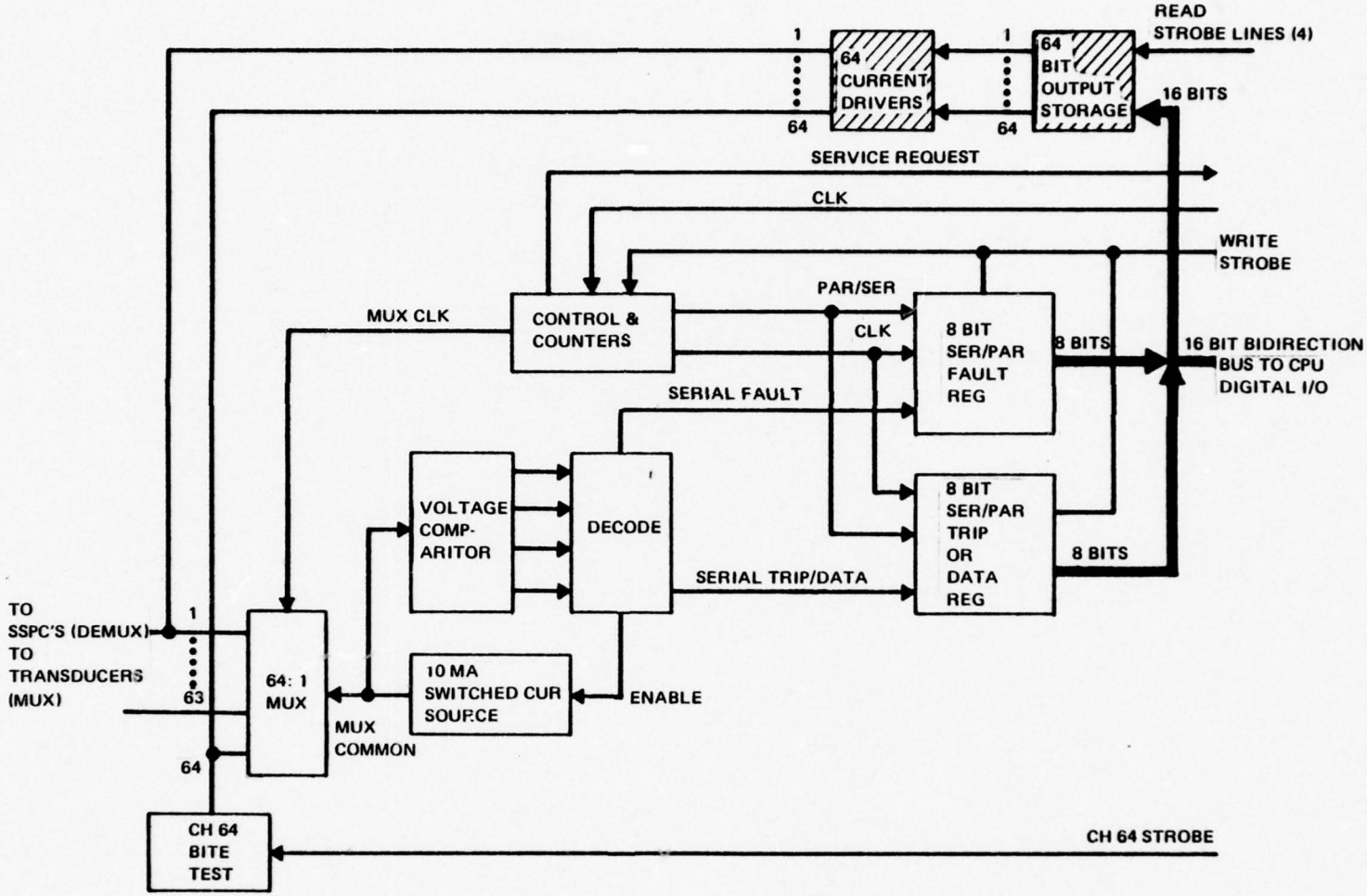


Figure 4-99. 3000 "Smart" Terminal - SOSTEL MUX/DEMUX I/O (Add Cross Hatched Blocks for DEMUX)

A two-channel bus layout for the F-14 is incorporated in Subsection 4.2.7. The layout is aimed at providing maximum separation between each cable. This is accomplished by routing the primary cable high on the port side and low on the starboard side; the secondary cable is low on the port side and high on the starboard side. Crossover of the cables occurs forward of the pilots cockpit and terminate at the aftmost control group components.

4.2.6.4 Solid State Transducers

The SOSTEL MUX's are designed to sample solid state transducers or suitably conditioned switched impedance signal sources by strobing with a 50 usec, 10 ma current pulse. The MUX encodes the resultant voltage which identifies the state of the transducer as follows:

State of Transducer	Impedance, ohms	Resultant Voltage, volts
Short	0-300	0-3.0
ON	378-472	3.78-4.72
OFF	648-802	6.48-8.02
Open	1K-1.2K	10-12

The short and open conditions are part of the BIT information for detecting faulty transducers or wiring. To satisfy the SOSTEL requirements, a solid state transducer must be electrically energized by the strobe current. This calls for a device which, in its simplest form (single pole), will have a single port, (control current input and ground reference) and can provide the on/off impedance levels without an electrical path through the mechanical elements. A solid state transducer which electrically meets these requirements was breadboarded and is illustrated in Fig. 4-100.

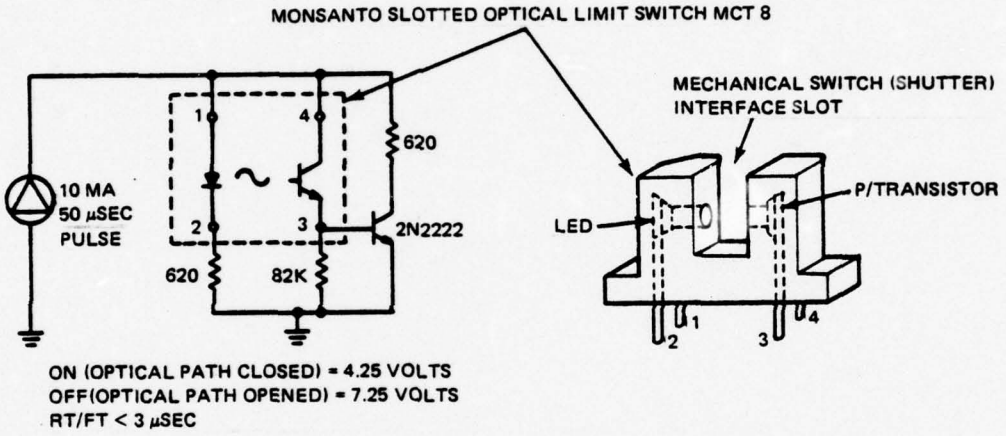


Figure 4-100. Typical Solid State Transducer

4.2.7 SOLID STATE POWER CONTROLLERS - EVALUATION AND SELECTION

Five hundred and forty four Boolean equations (representing approximately 93% of the aircraft circuit breakers) have been derived (see Tables III of Appendix B).

An analysis of these equations indicates that the SOSTEL system must drive power and discrete loads categorized as follows:

Voltage	Load Range
28 vdc	Discretes, flags, lights, etc (up to 250 ma)
28 vdc	2, 5, and 10 amp
115 v, 400 Hz	2 and 5 amp (1 and 3 Ø)
115 v, 400 Hz	5 to 10 amp (1 and 3 Ø)
115 v, 400 Hz	30 amp (3 Ø) motor load
26 v, 400 Hz	2 amp (1 Ø)

The load drivers selected are

- 28 vdc discretes will be driven by GPMS I/O's
- 28 vdc, (2, 5 and 10 amp) loads will be driven by solid state power controllers per MIL-P-81653/2A
- 115 v, 400 Hz (2 and 5 amp) loads will be driven by solid state power controllers per MIL-P-81653/4A
- 115 v, 400 Hz (5 to 10 amp) power loads will be driven by a single-pole hybrid power controller to preclude the development of a 10 amp solid state power controller and to minimize the power dissipation. The estimated power dissipation and form factor of the hybrid presented below was obtained by combining a 10-amp, solid state controller per MIL-P-81653/4A with a 10-amp MS 27401 relay.

	Form Factor, in.	Power Dissipation, watts	
		5 amp	10 amp
Hybrid	1.75 x 1.27 x 1	6.5	6.5
Solid State	1.27 x 1.27 x 1.1	9	16.5

All three-phase loads (up to 10 amp) will be driven by three separate single-pole hybrid controllers in lieu of developing a ganged three-pole solid state power controller. Also,

- 115 v, 400 Hz (30 amp, 3 ø) motor loads will be driven by a 3 pst remote control circuit breaker per MIL-C-83383, modified to incorporate BIT. The estimated size is 5 x 3-1/4 x 3-3/4 in. with a power dissipation of 15 w
- 26 v, 400 Hz loads will be driven by a MIL-P-81653 115 v, 2 amp controller through a step-down, low-power 115 v/26 v transformer. This will preclude the requirement to develop a 26 v, 400 Hz controller.

4.2.8 BUS CONTROLLERS - EVALUATION AND SELECTION

The present F-14A maximum continuous total current utilization (during cruise combat mode), is approximately 600 amp at 115 v, 400 Hz. Therefore, for the SOSTEL's prototype a-c bus approach, each phase must be provided with 200 amp bus protection.

Selecting the spst 115 v, 400-Hz, 75-amp bus controller per MIL-P-81653/7A would require using three controllers per phase at a total power dissipation of 375 w. As a result of their high dissipations, these controllers would require cooling beyond that presently available in the aircraft actively cooled compartments. Therefore, to preclude a change in the aircrafts ECS, the MIL-P-81653/7-amp bus controller was not selected.

The device selected is a 115-v, 400-Hz, 100-amp, remote-controlled circuit breaker (RCCB) per MIL-C-83383/2-13 modified to incorporate BIT. Two of these RCCB will be used for each phase. The estimated power dissipation for each RCCB is 10-w, which is compatible with the aircraft cooling system.

The estimated engineering effort to provide the BIT modification on presently available RCCB's is modest as indicated by our contacts with vendors such as Cutler Hammer.

The maximum continuous single bus 28 vdc current of 120-amp will be protected by two 28-vdc, 75-amp RCCB's per MIL-C-83383/2-11 modified to incorporate BIT. The availability of this RCCB is as described above for the a-c type.

4.2.9 LOAD AND BUS CONTROLLER INSTALLATION AND THERMAL ANALYSIS

The goal of this effort was to install the required load power controllers without removing or repositioning any existing WRA's other than those replaced by SOSTEL equipments (circuit breakers, relays, etc), and to minimize the impact on the ECS. As the subsequent discussion reveals, these goals are realistic and achievable.

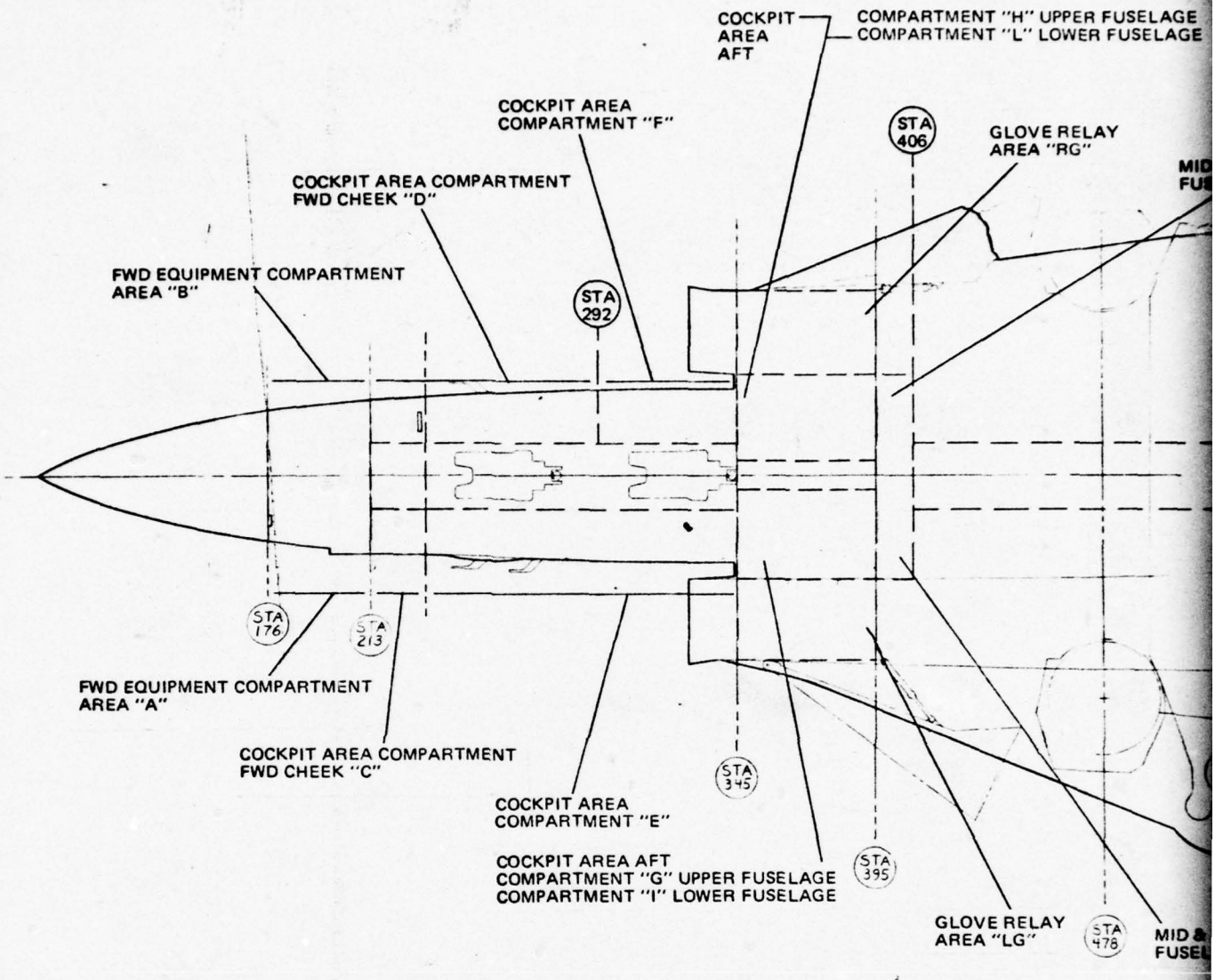
An analysis of the 544 Boolean equations indicates that ths SOSTEL system requires 415 load power controllers as summarized in Table 4-44. The compartment locations were selected so that the controllers were either in the same compartment as their loads or as close to them as physically possible. The selected compartment area locations are as illustrated in Fig. 4-101, and are accessible by removing fuselage access panels.

An inspection of Table 4-44 reveals that 299 (72% of the total) load controllers must be installed in equipment compartments forward of Station 406. These compartments are actively cooled to an ambient of 160^{o}F by the ECS, and are acceptable areas for the load power controllers provided that their packaging provides adequate thermal dissipation.

A survey of the available compartment volumes indicated that sufficient volume is available to install all the required load power controllers. However, these volumes were in most instances low profile (approximately 2 in.), and offered somewhat restricted length and width dimensions. Therefore, to establish a baseline for the packaging, installing, and thermal compatibility study, SSPC and hybrid module assemblies per Fig. 4-102 and 4-103, respectively, were selected.

TABLE 4-44. LOAD POWER CONTROLLER SUMMARY

Location	Compartment	28 vdc			115 V, 400 Hz				TOTAL
		2 a	5 a	10 a	2 a	5 a	10 a	30 a	
Fwd Equipment Compart., Port Side	A		1		4	4	4		13
Fwd Equipment Compart., Stbd Side	B	8	2		14	2	4		30
Cockpit Area Compart., Port Side - FWD Cheek	C	3		1	2				6
Cockpit Area Compart., Stbd Side - FWD Cheek	D	23	4		12	4			43
Cockpit Area Compart., Port Side	E				2				2
Cockpit Area Compart., Stbd Side	F						3		3
Cockpit Area Compart., Port Side-Aft	G	6		2	16				24
Cockpit Area Compart., Stbd Side-Aft	H	1			15	1	3		20
ECS Compart., Stbd Side	L	11	3				3		17
Cockpit Area Compart., Port Side - Aft Cheek	I	5	1		14	1			21
Mid and Aft Fuselage Compart.	J&K	3	14	1	14				32
Glove Relay Area, Port Side	LG	15	2	-	32			1	50
Glove Relay Area, Stbd Side	RG	12	1	1	21		3		38
Sponson Area, Port Side	YLF	5	2	1	4				12
Sponson Area, Stbd Side	YRT	4	2	1	3				10
Bottom Centerline of Aircraft	P	8	2	16	4		27		57
Flight Control Trough	U	7	4		13				24
Upper Aft End of Fuselage	V	5	1		6			1	13
TOTAL		116	39	23	176	12	47	2	415


COCKPIT AREA AFT
COMPARTMENT "H" UPPER FUSELAGE
COMPARTMENT "L" LOWER FUSELAGE
COCKPIT AREA COMPARTMENT "F"
STA 406
GLOVE RELAY AREA "RG"
COCKPIT AREA COMPARTMENT FWD CHEEK "D"
FWD EQUIPMENT COMPARTMENT AREA "B"
STA 292
STA 176
STA 213
FWD EQUIPMENT COMPARTMENT AREA "A"
COCKPIT AREA COMPARTMENT FWD CHEEK "C"
STA 345
COCKPIT AREA COMPARTMENT "E"
COCKPIT AREA AFT COMPARTMENT "G" UPPER FUSELAGE COMPARTMENT "I" LOWER FUSELAGE
STA 395
GLOVE RELAY AREA "LG"
STA 478

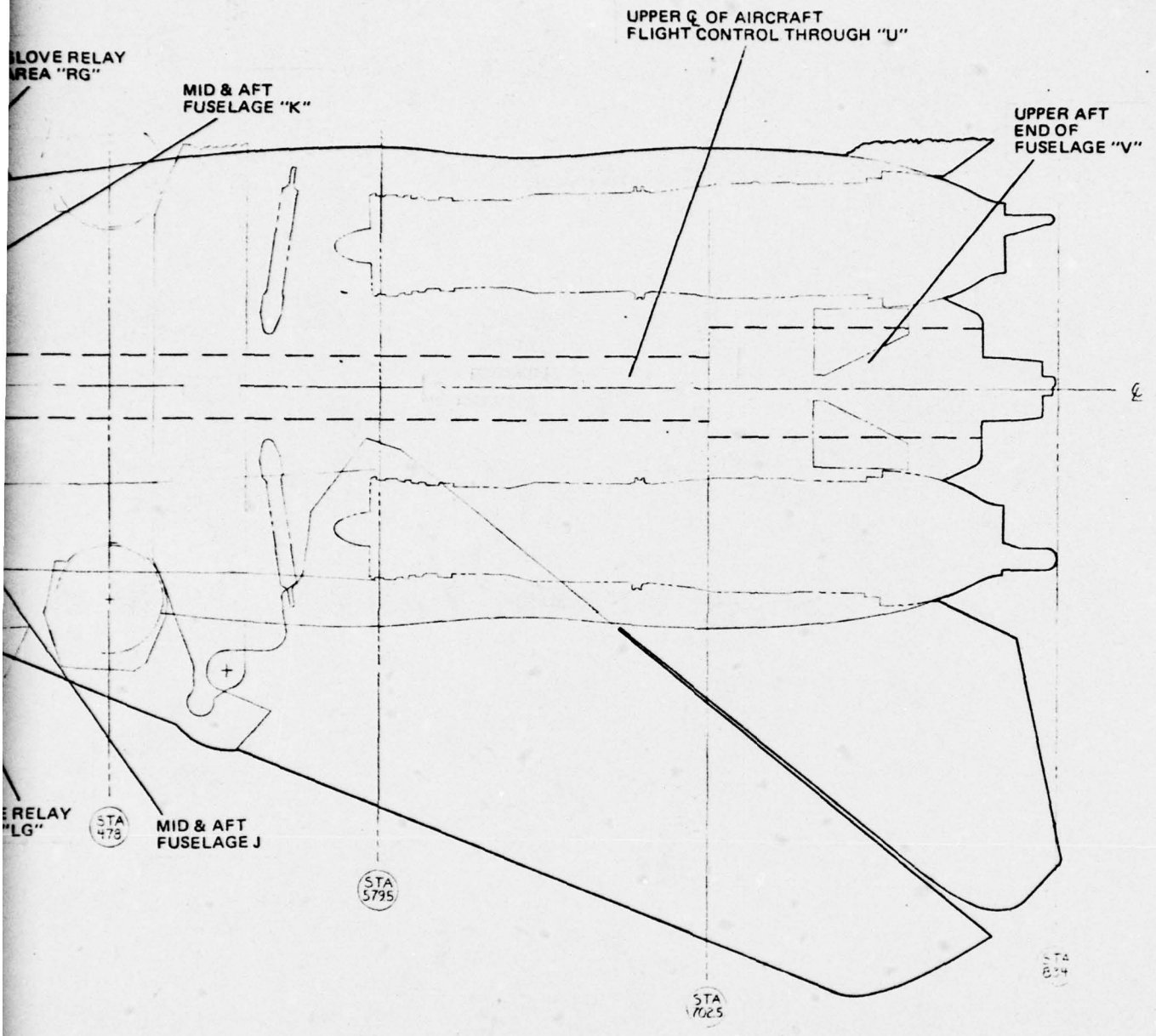
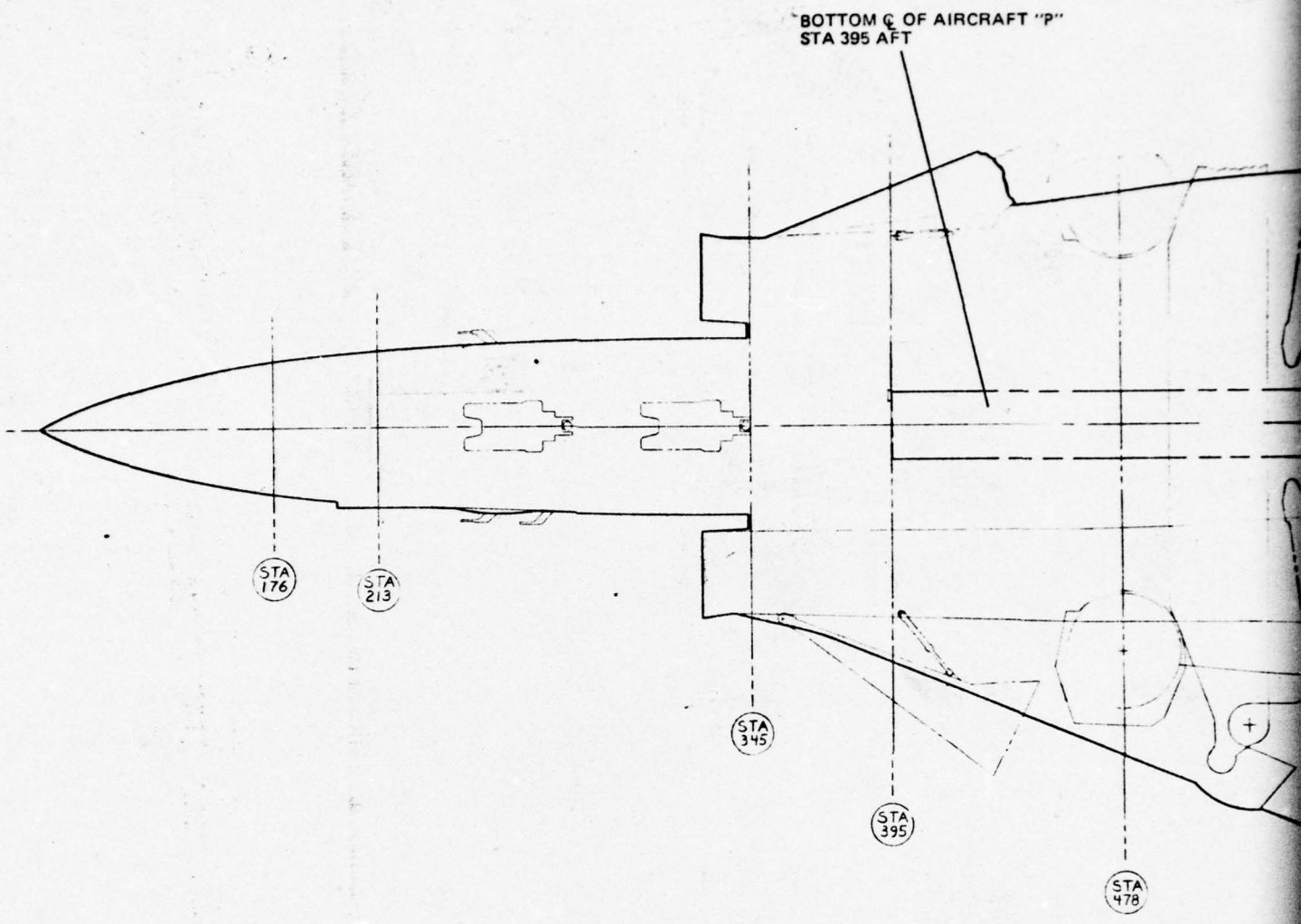


Figure 4-101. Compartment Locations
(Sheet 1 of 2)


BOTTOM ℄ OF AIRCRAFT "P"
STA 395 AFT
STA 176
STA 213
STA 345
STA 395
STA 478

SPONSON ARE

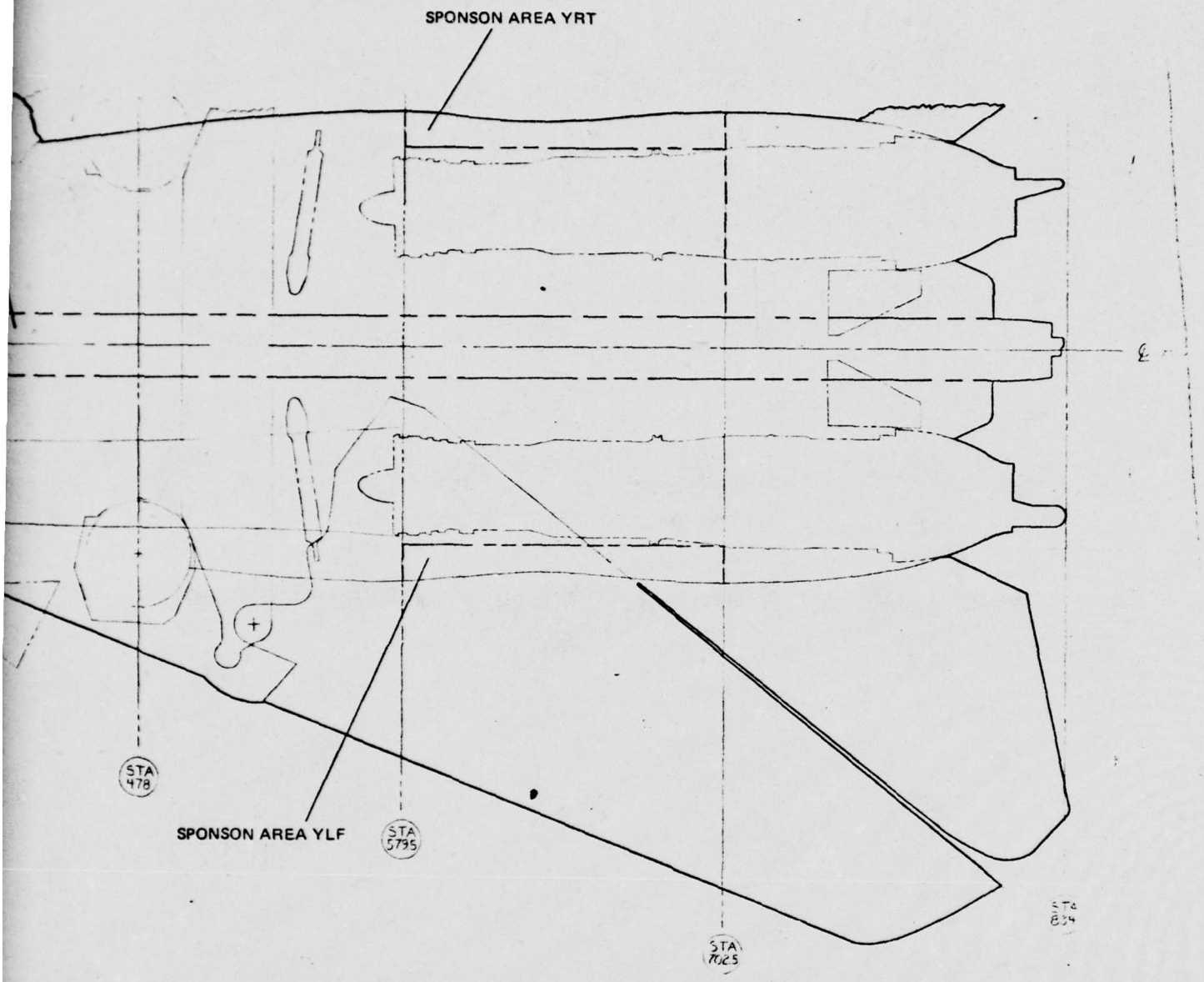


Figure 4-101. Compartment Locations
(Sheet 2 of 2)

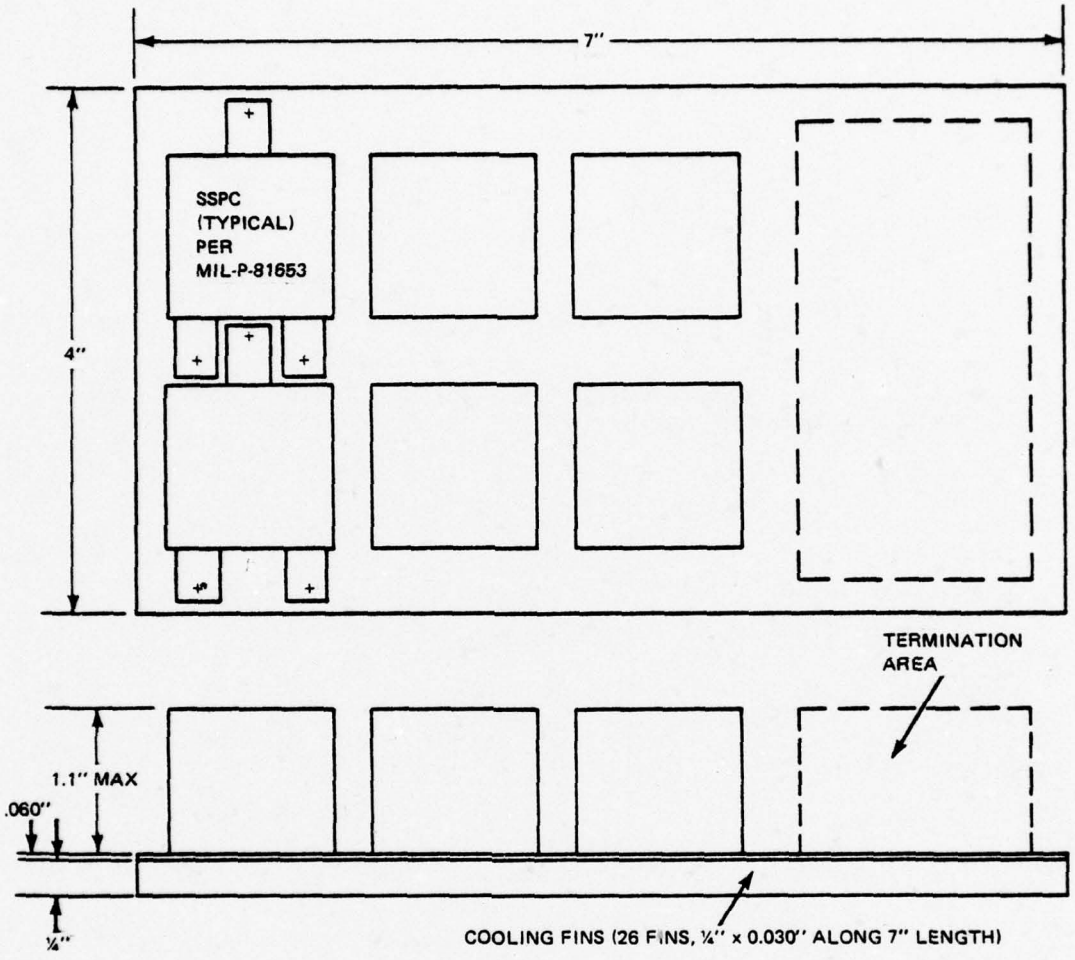


Figure 4-102. SSPC Module Assembly

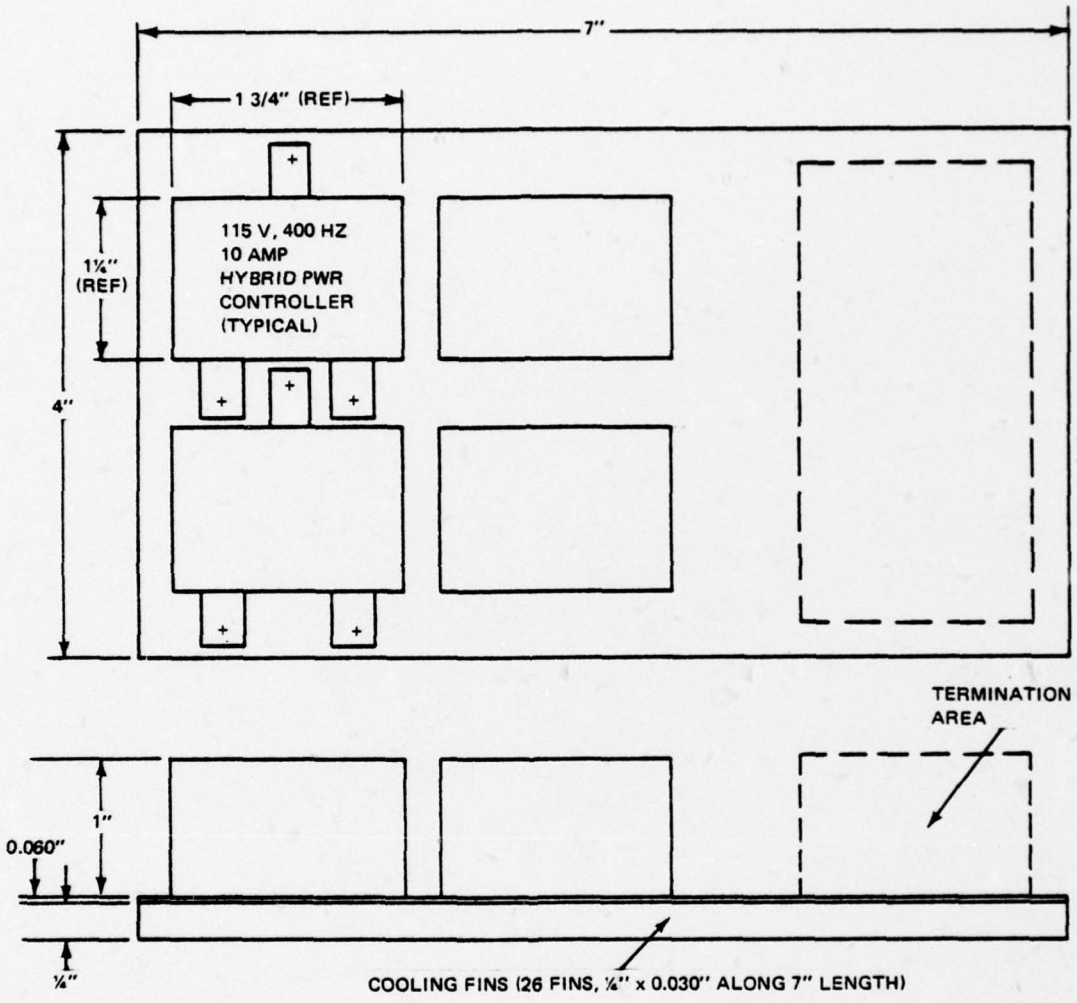


Figure 4-103 Hybrid Module Assembly

For the SSPC and hybrid module assemblies of Fig. 4-102 and 4-103, a thermal analysis indicates that for the surface areas available a maximum of 20 w can be dissipated in the available compartment environments such that the controller heat sink temperature is maintained below 100°C.

Therefore, the total power dissipation of any one module assembly must be less than 20 w. In fact, the lower the case temperature, the greater the MTBF (see Fig. 4-104). This curve was calculated from data extracted from the Report prepared under Number N62269-72-C-0642, entitled "DC Power Controller with BIT prepared by RCA for NADC. Table 4-45 presents a summary of the loads by compartment and also includes:

- Load current
- Controller rating
- Controller dissipation
- Controller identification
- Load or data bus
- Reference figure (NAVAIR 01-F14AAA-2-2-16)
- Controller module No.
- Operational address.

The controller dissipations were obtained from curves (Fig. 4-105 and 4-106) derived from data in MIL-P-81653/2A and 4A. The actual power dissipations of the controller modules at 100% duty cycle are as tabulated in Table 4-46. The heat sink temperatures are included for reference.

Included in Table 4-46 are the 185 discrete load signals required by compartment, which as previously mentioned will be driven by GPMS I/O's, and the eight bus controllers which will be installed in compartments I and L.

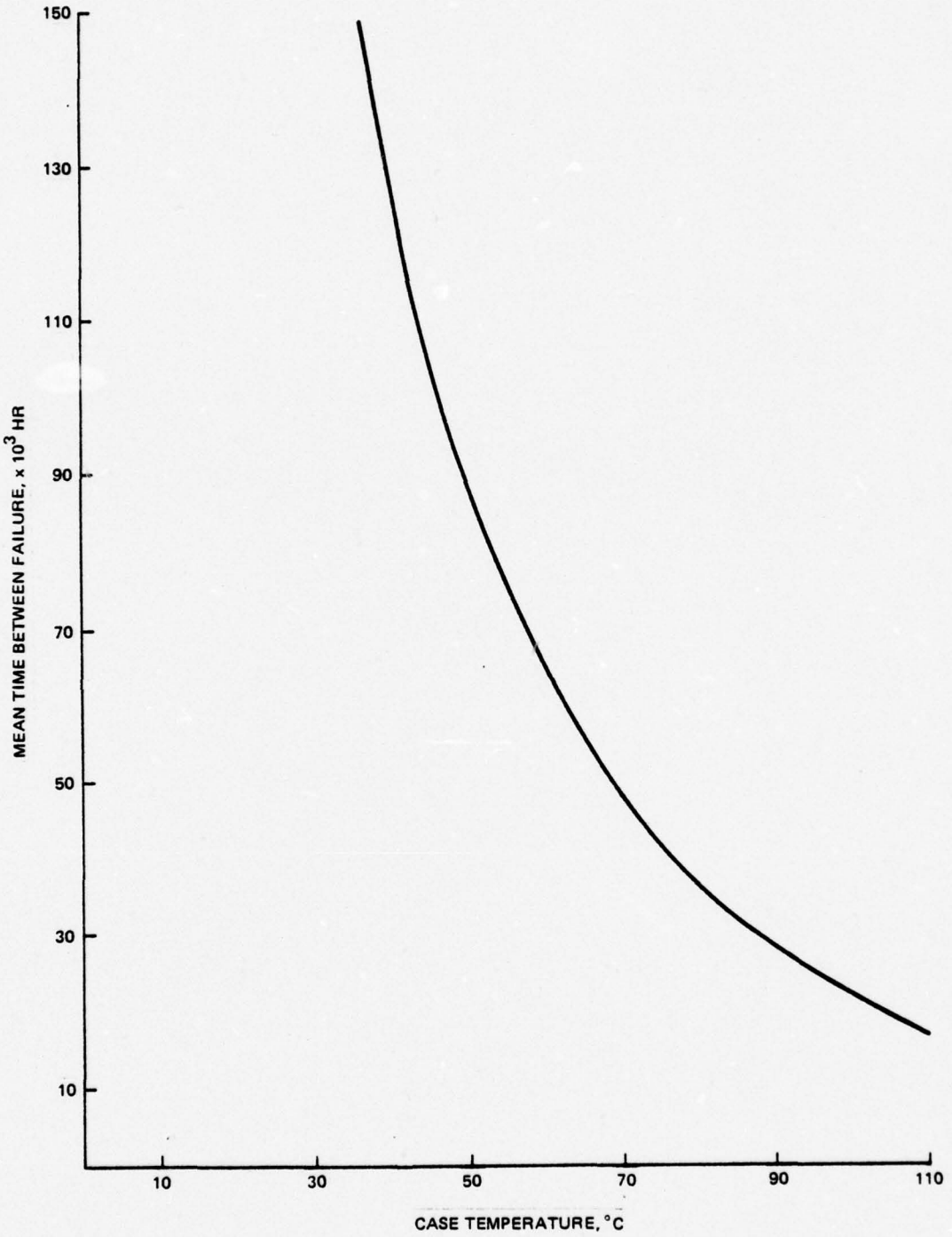


Figure 4-104. MTBF Vs. Case Temperature for RCA 5-A, 28-VDC Solid State Power Controller

TABLE 4-45. COCKPIT GPMS DT O1D (SHEET 1 OF 33)

Item	Load Description	Ident	Ref. Fig	Operational Address	
1	Lamp (NFO Cabin Press)	HPL 220	32	O1D 01	
2	" (Pilots L Oil hot)	EML 217	32	02	
3	" (Pilots Bleed Duct)	HNL 223	32	03	
	" (Go Test & PWR)				
4	" (Pilot Windshield Hot)	LTL 173	33	04	
5	" (Pilot HYD Press)	DHL 273	35	05	
6	Indicator (HYD. Press)	DHL 274	35	06	
7	Flag (Emer. Flight Hydraulic Ind, Low)	DHL 275	35	07	
8	" " " " " Hi)	DHL 276	35	08	
9	Indicator (HYD. Press. Spoilers)	DHL 180	37	09	
10	Tone Generator (Pilots)	EWL 182	38	10	
11	Lamp (R. Oil hot pilot's)	EML 190	38	11	
12	Lamp (R. OVSP/Valve Pilot's)	EUL 229	40	12	
13	" (L " " ")	EUL 230	40	13	
14	" (Go/No Go Master Test PNL)	QAL 504	41	14	
15	" (L. Fuel Low, NFO's PNL)	EJL 246	42	15	
16	" (L. " " Pilot's ")	EJL 247	42	16	
17	" (R. " " " ")	ERL 248	42	17	
18	" (R. Fuel Press. Pilots PNL)	ERL 249	42	18	
19	" (L. " " " ")	ERL 250	42	19	
20	" (Fuel Press)	ERL 251	42	20	
21	" (Pilots Bingo)	ERL 252	42	21	
22	" (Eject Command Ind. Pilots LN GR Cont)	WFL 560	43	22	
23	Relay (Liquid Quantity Ind.)	WHL 562	43	23	
24	Enable DR. (L. Alarm Cont). Fire Detection (R. " ") Short Test	WGL 568	43	24	
25	Lamp (L. Fire, ACM PNL Pilot's)	WGL 569	43	25	
26	" (R. Fire ACM PNL Pilot's)	WGL 570	43	26	
27	Flag (Speed Brakes - Pilot)	NAL 575	43	27	
28	" (" " Partial Ind)	NAL 576	43	28	
29	" " " Full "	NAL 577	43	29	
30	Lamp (Go Lamp Master Test PNL)	DUL 578	43	30	
31	" (No Go " " " ")	DUL 579	43	31	
32	" (Eject Command Ind, Pilots LN. GR, PNL)	WFL 591	43	32	
33	Enable Driver (L. Alarm Cont. Fire Test Sw. Sig (R. " " " " " ")	WGL 592	43	33	
34	Enable Driver (Dim Sig. on Pilot Cau. Adv. PNL)	DUL 530	46	34	
35	" " " " " NFO " " "	DUL 531	46	35	
36	" " (Lights Test NFO Cau. Adv. PNL)	DUL 532	46	36	
37	Lamp (R. RAM Cau. Pilots Cau. Adv. PNL)	DUL 539	46	37	
38	" (L RANP Cau.)	DUL 540	46	38	
39	Enable Driver (Wing Sweep Ind.)	DUL 541	46	39	
40	Lamp (HZ Tail Auth. Ind. Pilot Cau. PNL)	DUL 543	46	40	
41	" R. Gen. Pilots Cau. & Adv.)	DUL 546	46	41	
42	" (L. Gen. " " " ")	DUL 549	46	42	
43	" (Xformer/Rec. Pilots Cau. & Adv)	DUL 550	46	43	
44	" (Oil Press. " " " ")	DUL 551	46	44	
45	" (Launch Bar Lamp Pilots Cau. & Adv.)	DUL 552	46	45	
46	" (Inlet Ice " " " ")	HAL 553	46	46	
47	" (Canopy Lgts Pilots and NFO's Cau. & Adv)	DUL 554	46	47	
48	" (OXY. Low " " " " ")	WHL 555	46	48	
49	" (Ladder Lgt Pilots Cau. & Adv. PNL)	DUL 556	46	49	
50	" (Cooling Air NFO's Cau. & Adv. PNL)	HNL 557	46	50	
51	" (Radar Lgt " " " " ")	SVL 558	46	O1D 51	

TABLE 4-45 COCKPIT GPMS DT 02D (SHEET 2 OF 33)

ITEM NO.	LOAD/FUNCTION	IDENT.	REF FIG.		
1	Flag (Cont. Sur. Pos. Ind. Rt. Inb'rd Spoil.UP)	DLL 314	1	02D 01	
2	" " " " Lf.	DLL 315	1	02	
3	" " Droop	DLL 316	1	03	
4	" " " " " Rt.	DLL 317	1	04	
5	" " " " Lf. Outbd Up	DLL 318	1	05	
6	" " " Droop	DLL 319	1	06	
7	" " " Rt. Up	DLL 320	1	07	
8	" " " Droop	DLL 321	1	08	
9	Standby Light DECM Cont. PNL	TEL 711	1A	09	
10	Relay Driver " " "	TEL 712	1A	10	
11	Enable " Chaff/Flare Dispense	TEL 714	1A	11	
12	Sweep Indicator	GEL 106	2	12	
13	Lamp No Go Test (Sys Test,Sys Pwr Pnl)	HJL 117	2	13	
14	" Go " " "	HJL 118	2	14	
15	Wheel Flaps Pos. Ind.	CGL 119	2	15	
16	High Indexer Light Driver	LAL 120	3	16	
17	Low " " "	LAL 121	3	17	
18	Normal" " "	LAL 122	3	18	
19	Angle of Attack Indicator	FDL 123	3	19	
20	NFO Main Data Link Control PNL Pilot " " " " "	RPL 718	3A	20	
21	Computer Data Term. (Align Data Select)	RPL 725	3A	21	
22	" " " (Way Point Data Select)	RPL 726	3A	22	
23	NFO UHF Remote Indicator Pilot" " "	RUL 043	8	23	
24	Light (AAI Control PNL)	SXL 057	9	24	
25	Light (IFF Control PNL)	SXL 061	10	25	
26	Relay Driver (Pilots Mach Air Speed Ind)	FLL 377	15	26	
27	Logic Driver (Armament PNL)	AML 148	16	27	
28	" " "	AML 149	16	28	
29	" " "	AML 150	16	29	
30	Lamp (Emergency Jett. Pushbutton Sw)	AML 151	16	30	
31	Enable Driver (Safety Override Arm. PNL)	AGL 153	16	31	
32	" " (MLG HDL DN ARM. PNL)	AGL 154	16	32	
33	" " (" " UP " ")	AGL 155	16	33	
34	" " (ALM JETT. SEL. Arm. PNL)	AGL 156	16	34	
35	" " " " " " "	AGL 157	16	35	
36	" " (NLG Door Up & Lock Signal)	AAL 325	17	36	
37	" " (MLG HDL DN Signal)	AAL 326	17	37	
38	" " (Target Designator Up Sig.)	AAL 328	17	38	
39	" " (" " Signal)	AAL 329	17	39	
40	" " (" " DN Signal)	AAL 330	17	40	
41	" " (AW IN-4-2 & UDC Arm. PNL)	AAL 331	17	41	
42	" " (GUN Cage CMD " ")	ADL 333	18	42	
43	" " (GUN Slect Arm. PNL)	ADL 336	18	43	
44	" " (AIM 9 Select Arm. PNL)	YAL 379	19	44	
45	" " (" " Station Select)	YAL 380	19	45	
46	Flag (NLG DN & Lock to Wheels Flap Pos. Ind)	GDL 288	30	46	
47	" (Wheel Flops Pos. Ind)	GLL 289	30	47	
48	" (NLG UP & Locked)	GJL 290	30	48	
49	" (Lf MLG DN & Locked)	GDL 291	30	49	
50	" (" " UP " ")	GJL 292	30	50	
51	" (RT " DN " ")	GDL 293	30	51	
52	" (RT " UP " ")	GJL 294	30	52	
53	Lamp (Aux BRK/Skid Caution)	GLL 295	30	53	
54	Lamp (Hook Transit Ind.)	GGL 297	30	54	
55	Lamp (Transit Ind)	GGL 298	30	55	
56	Enable Driver (DN & Lock GND INPUT)	MJL 299	30	02D 56	

TABLE 4-45 COMPARTMENT A - FORWARD EQUIPMENT COMPARTMENT (SHEET 3 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Angle of Attack X'mitter HTR Left Total Temp. Probe HTR	5.2	115V, 10A	6.5	HAL 026	ØC	3	A2	01Q01	Hybrid Power Controller
2	Left AICS ∠ of Attack Probe HTR	2.3	115V, 5A	4.5	HAL 028	ØB	4	A2	01Q02	
3	Infrared Amplifier & Receiver	2.6	115V, 5A	4.6	THL 746	ØA	5A	A1	01Q03	
4	Infrared Amplifier & Receiver	2.6	115V, 5A	4.6	THL 746	ØB	5A	A1	01Q04	
5	Infrared Amplifier & Receiver	2.6	115V, 5A	4.6	THL 746	ØC	5A	A1	01Q05	
6	Infrared Amplifier IR/TV (on select)	---	---	---	THL 747	GPMS	5A	---	04D01	Enable Drive
7	Infrared Amplifier	3	28V, 5A	3.5	THL 749	DC	5A	A2	01Q06	
8	Infrared Amplifier IR/TV (Stby Select)	---	---	---	THL 748	GPMS	5A	---	04D02	Enable Drive
9	UHF/ADF Antenna	.5	115V, 2A	1.2	RUL 055	ØA	8	A1	01Q07	115V/26V X'former load
10	ARN-84 TACAN Receiver X'mitter AHRS Amplifier	1	115V, 2A	2.5	RNL 068	ØA	14	A2	01Q08	
11	IMU Power Supply	5.7	115V, 10A	6.5	RNL 072	ØA	14	A3	01Q09	Hybrid Power Controller
12	IMU Power Supply	5.7	115V, 10A	6.5	RNL 073	ØB	14	A3	01Q10	Hybrid Power Controller
13	IMU Power Supply	5.7	115V, 10A	6.5	RNL 074	ØC	14	A3	01Q11	Hybrid Power Controller
14	Fuselage Anti Collison Light	1.3	115V, 2A	2.5	LNL 160	ØA	44	A2	01Q12	
15	Beam Power Supply	1.5	115V, 2A	3.2	TBL 731	ØA	4A	A1	01Q13	

TABLE 4-45 COMPARTMENT B - FORWARD EQUIPMENT COMPARTMENT - STARBOARD SIDE (SHEET 4 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Radar Antenna	2	115V, 2A	4.0	TBL 730	ØA	4A	B1	04Q01	
2	Radar X'mitter	3	115V, 5A	5.4	TBL 733	ØB	4A	B_1	02	
3	Radar Synchronizer	4	115V, 5A	6.9	TBL 734	ØC	4A	B1	03	
4	Radar RCVR	3	28V, 5A	3.5	TBL 735	DC	4A	B_3	04	
5	Radar Antenna	9.5	115V, 10A	6.5	TBL 736	ØA	4A	B6	05	Hybrid Power Controller
6	Radar Antenna	9.5	115V, 10A	6.5	TBL 736	ØB	4A	B6	06	Hybrid Power Controller
7	Radar Antenna	9.5	115V, 10A	6.5	TBL 736	ØC	4A	B6	07	Hybrid Power Controller
8	Radar Synchronizer	5	28V, 5A	4.5	TBL 751	DC	5A	B3	08	
9	Beacon Augmenter	1	28V, 2A	1.5	TPL 125	DC	7	B4	09	
10	IMU Power Supply	1.9	115V, 2A	4.0	RNL 069	ØA	14	B5	10	
11	IMU Power Supply	1.9	115V, 2A	4.0	RNL 070	ØB	14	B5	11	
12	IMU Power Supply	1.9	115V, 2A	4.0	RNL 071	ØC	14	B5	12	
13	Windshield Power Control	5.7	115V, 10A	6.5	HJL 168	ØC	33	B3	13	Hybrid Power Controller
14	Rain Repellant Shut-off Valve	1.5	28, 2A	1.8	HJL 172	DC	33	B4	14	
15	Windshield Power Control	1.5	28, 2A	1.8	HJL 174	DC	33	B3	15	
16	Refueling Probe Solenoid Selector Valve (Ext.- All)	1.5	28, 2A	1.8	QAL 500	DC	41	B4	16	
17	Refueling Probe Solenoid Selector Valve (Ext- Fuslg Sol. A)	1.5	28, 2A	1.8	QAL 501	DC	41	B4	17	
18	Refueling Probe Sol. Sel. Valve (Ext- Fuslg Sol. B)	1.5	28, 2A	1.8	QAL 502	DC	41	B4	18	
19	Refueling Probe Sol. Sel. Valve (Ext. Fuslg- Sol. C)	1.5	28, 2A	1.8	QAL 503	DC	41	B4	19	
20	Windshield Power Control	2	28V, 2A	2.0	HKL 564	DC	43	B3	20	
21	Probe Light	.53	115V, 2A	1.7	LML 158	ØB	44	B5	21	
22	Multi-Channel Lighting	2	115V, 2A	4.0	LFL 167	ØB	44	B2	22	
23	NFO Instrument Lights Control Channel 7	1.1	115V, 2A	2.6	LHL 505	ØB	45	B2	23	

TABLE 4-45 COMPARTMENT B - FORWARD EQUIPMENT COMPARTMENT - STARBOARD SIDE (SHEET 5 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
24	NFO White Flood Light Control Channel 9	1.0	115V, 2A	2.5	LHL 506	ØB	45	B2	04Q24	
25	NFO Console Light Control Channel 2	1.4	115V, 2A	3.1	LHL 507	ØA	45	B2	25	
26	NFO Red Flood Light	.9	115V, 2A	2.5	LHL 508	ØC	45	B5	26	
27	Pilots Instrument Light	1.1	115V, 2A	2.5	LHL 511	ØB	45	B2	27	
28	Pilots White Flood Light	1.0	115V, 2A	2.5	LHL 512	ØB	45	B1	28	
29	Pilots Console Light	1.4	115V, 2A	3.1	LHL 513	ØA	45	B2	29	
30	Pilots Red Flood Light	.9	115V, 2A	2.5	LHL 514	ØC	45	B5	04Q30	

TABLE 4-45 COMPARTMENT C - COCKPIT AREA COMPARTMENT - PORT SIDE FORWARD CHEEK (SHEET 6 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Throttle Control Computer (Power Supply)	1.9	115V, 2A	4.0	QKL 031	ØA	5	C1	01Q14	
2	Throttle Control Computer - Engage	---	---	---	QKL 112	GPMS	5	---	04D03	Enable Drive
3	Throttle Control Computer Boost Enable	---	---	---	QKL 113	GPMS	5	---	04D04	Enable Drive
4	Throttle Control Computer - WOW	---	---	---	QKL 114	GPMS	5	---	04D05	Enable Drive
5	Throttle Control Computer - Auto Enable	---	---	---	QKL 115	GPMS	5	---	04D06	Enable Drive
6	Throttle Control Computer Auto Ground Intl'k	---	---	---	QKL 116	GPMS	5	---	04D07	Enable Drive
7	Beacon Receiver X'mitter	2	28V, 2A	2.0	TPL 124	DC	7	C1	01Q15	
8	Gun Controller (Power Supply)	1.5	115V, 2A	3.2	ADL 332	ØB	18	C_1	01Q16	
9	Gun Controller (Gun Clear/Gun Control) Purging Switching Assy	9.75	28V, 10A	7.4	ADL 335	DC	18	C^1	01Q17	
10	Purging Switching Assy (Trigger Interrupt Enable)	2.0	28V, 2A	2.0	ADL 337	DC	18	C1	01Q18	
11	Throttle Control Computer (Pilot OBC Select)	---	---	---	MJL 582	GPMS	43	---	04D08	Enable Drive
12	Cabin Pressure Safety Valve Solenoid	1.5	28, 2A	1.8	HPL 220	DC	32	C1	01Q19	

TABLE 4-45 COMPARTMENT D - COCKPIT COMPARTMENT AREA FWD CHEEK - STARBOARD SIDE (SHEET 7 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	RT. AICS Total Temp Probe Heater RT. ∢ of Attack Probe Heater	2.3	115V, 5A	4.5	HAL 027	ØC	4	D3	04Q31	
2	Main UHF Receiver X'mitter	4.7	28V, 5A	4.3	RUL 041	DC	8	D7	04Q32	
3	Main UHF Antenna Selector Pilot Comm./Nav. Cmd. Panel	1.5	28V, 2A	1.8	RUL 042	DC	8	D7	04Q33	
4	Crypto Graphic Unit On/Off Cont.	1.2	28V, 2A	1.6	RPL 047	DC	8	D4	04Q34	
5	Crypto Graphic Unit Relay Cont.	---	---	---	RPL 048	GPMS	8	---	06D01	GND/Open (Enable Driver)
6	Crypto Graphic Unit Plain/Cipher	---	---	---	RPL 049	GPMS	8	---	06D02	28V/GND (Enable Driver)
7	Crypto Graphic Unit (Zeroize)	.5	28V, 2A	1.3	RPL 050	DC	8	D6	04Q35	
8	Main UHF X'mitter	.5	115V, 2A	1.6	RUL 051	ØA	8	D1	04Q36	
9	Main UHF X'mitter	.5	115V, 2A	1.6	RUL 052	ØB	8	D1	04Q37	
10	Main UHF X'mitter	.5	115V, 2A	1.6	RUL 053	ØC	8	D1	04Q38	
11	Interrogator Computer Mode 4 Code Zeroize Gen.	.4	28V, 2A	1.2	SXL 058	DC	9	D7	04Q39	
12	Interrogator Computer	.100	---	---	GJL 059	GPMS	9	---	06D03	GND/Open (Enable Driver)
13	AHRS Amplifier	1.0	115V, 2A	2.5	RNL 068	ØA	14	D1	04Q40	
14	Extend Solenoid (P/O NLG Transfer Valve)	1.5	28V, 2A	1.8	GAL 279	DC	30	D4	04Q41	
15	Kneel Solenoid (P/O NLG Transfer Valve)	1.5	28V, 2A	1.8	GAL 280	DC	30	D4	04Q42	
16	Sequencing Solenoid (P/O NLG Sequencing Cont. Valve)	1.5	28V, 2A	1.8	GAS 281	DC	30	D4	04Q43	
17	Selector Solenoid (P/O Launch Bar Abort Selector Valve)	1.5	28V, 2A	1.8	GAL 282	DC	30	D4	04Q44	
18	Hook Solenoid (P/O Arresting Hook Cont. Valve)	1.5	28V, 2A	1.8	GGL 283	DC	30	D4	04Q45	
19	Uplock Solenoid (P/O Arresting Hook Cont. Valve)	1.5	28V, 2A	1.8	GGL 284	DC	30	D5	04Q46	
20	Nose Wheel Steering Monitor Solenoid	1.5	28V, 2A	1.8	GKL 286	DC	30	D7	04Q47	
21	Skid Box Control (Power Supply)	4.0	28V, 5A	4.0	GKL 285	DC	30	D5	04Q48	
22	Shut Off Solenoid (P/O Nose Wheel Steering Damper Unit)	1.5	28V, 2A	1.8	GHL 287	DC	30	D7	04Q49	

TABLE 4-45 COMPARTMENT D - COCKPIT COMPARTMENT AREA FWD CHEEK - STARBOARD SIDE (SHEET 8 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
23	Skid Control Box	---	---	---	GDL 296	GPMS	30	---	06D04	GND/Open (Relay Driver)
24	ETI (P/O Bootstrap Turbine Compressor)	.250	115V, 2A	1.2	DTL 196	ØC	32	D 2	04Q50	
25	Aircraft Air Temp. Electronic Cont. (P/O Cabin Air. Cond. Sys) Pwr. Supply	1.0	115V, 2A	2.5	HNL 197	ØC	32	D 2	04Q51	
26	Ground Cooling Diverter Valve Actuator - Retract (Motor)	1.5	115V, 2A	3.2	HNL 200	ØC	32	D 2	04Q52	
27	Ground Cooling Diverter Valve Actuator - Extend (Motor)	1.5	115V, 2A	3.2	HNL 201	ØC	32	D 2	04Q53	
28	Ground Cooling Diverter Door Actuator-Retract (Motor)	1.5	115V, 2A	3.2	HNL 202	ØC	32	D 2	04Q54	
29	Ground Cooling Diverter Door Actuator-Extend (Motor)	1.5	115V, 2A	3.2	HNL 203	ØC	32	D 2	04Q55	
30	Cooling Effect Controller (Heater)	3.0	28V, 5A	3.5	HNL 204	DC	32	D 3	04Q56	
31	Equipment Hot Air Modulating Valve Solenoid	1.5	28V, 2A	1.8	HNL 205	DC	32	D 3	04Q57	
32	Aircraft Air Temp. Electronic Control	---	---	---	HNL 215	GPMS	32	---	06D05	ON/OFF Enable
33	Aircraft Air Temp. Electronic Control	1.0	28V, 2A	1.5	HNL 216	DC	32	D 5	04Q58	
34	Cabin Hot Air Modulating Valve Cabin Air Flow Cont. Servo Valve (Motor) Position Switch Turbine Discharge Hot Air Valve (Motor) Position Switch P/O Switch Hot Air Modulating Valve	3.0	28V, 5A	3.5	HNL 218	DC	32	D 6	04Q59	
35	High Defog Solenoid	1.5	28V, 2A	1.8	HJL 169	DC	33	D 3	04Q60	
36	Med. Defog Solenoid	1.5	28V, 2A	1.8	HJL 170	DC	33	D 3	04Q61	
37	Windshield Anti-Ice Pressure Regulator and Shutoff Valve (Solenoid)	1.5	28V, 2A	1.8	HJL 171	DC	33	D 5	04Q62	
38	Engine Rotor Overspeed Detector Fuel Flow Indicator	.2	115V, 2A	1.2	EHL 188	ØB	38	D 1	04Q63	
39	Engine Rotor Overspeed Detector	1	28V, 2A	1.5	EML 189	DC	38	D 5	05Q01	
40	Signal Data Converter	.250	115V, 2A	1.2	EJL 236	ØB	42	D 8	05Q02	
41	RT. Electronic Control Amp. LF. Electronic Control Amp.	2	28V, 2A	2.0	EJL 245	DC	42	D 6	05Q03	

TABLE 4-45 COMPARTMENT D - COCKPIT COMPARTMENT AREA FWD CHEEK - STARBOARD SIDE (SHEET 9 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
42	Electronic Control Amp.	1.0	28V, 2A	1.5	EJL 253	DC	42	D7	05Q04	
43	Electronic Control Amp.	1.0	28V, 2A	1.5	EJL 254	DC	42	D5	05Q05	
44	Signal Data Converter (28V Bit Test)	1.0	28V, 2A	1.5	EJL 255	DC	42	D6	05Q06	
45	Signal Data Converter WG Select Switch	---	---	---	EJL 256	GPMS	42	---	06D06	On/Off (Enable Driver)
46	Signal Data Converter Feed Select Switch	---	---	---	EJL 257	GPMS	42	---	06D07	On/Off (Enable Driver)
47	Signal Data Converter Feed Select Switch	---	---	---	EJL 258	GPMS	42	---	06D08	On/Off (Enable Driver)
48	Signal Data Converter (28V Instrument Test Fuel)	1.	28V, 2A	1.5	EJL 259	DC	42	D3	05Q07	
49	Left Electronic Cont. Amp. (Fuel Low Level Test GND = Test Enable)	.100	---	---	EJL 260	GPMS	42	---	06D09	GND/Open
50	Rt. Electronic Cont. Amp. (Fuel Low Level Test GND = Test Enable)	.100	---	---	EJL 261	GPMS	42	---	06D10	GND/Open
51	Power Supply Bulk Storer	4.5	115V, 5A	7.6	TBL 728	ØA	4A	D8	05Q08	
52	Power Supply Bulk Storer	4.5	115V, 5A	7.6	TBL 728	ØB	4A	D8	05Q09	
53	Power Supply Bulk Storer	4.5	115V, 5A	7.6	TBL 728	ØC	4A	D1	05Q10	

TABLE 4-45 COMPARTMENT E - COCKPIT AREA - PORT SIDE (SHEET 10 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Data Link Converter	1.0	115V, 2A	2.5	RPL 719	ØA	3A	E1	01Q20	
2	Data Link Converter (Radiated Test Select)	---	---	---	RPL 720	GPMS	3A	---	04D09	Enable Drive
3	Data Link Converter (Forced Reply)	---	---	---	RPL 721	GPMS	3A	---	04D10	Enable Drive
4	Data Link Converter (Cancel Reply)	---	---	---	RPL 722	GPMS	3A	---	04D11	Enable Drive
5	Data Link Converter (UTM Select)	---	---	---	RPL 723	GPMS	3A	---	04D12	Enable Drive
6	Data Link Converter (Hardline Gains SEL)	---	---	---	RPL 724	GPMS	3A	---	04D13	Enable Drive
7	Interrogator Receiver Interrogator Switch Amplifier	2.0	115V, 2A	4.0	SXL 056	ØC	9	E1	01Q21	

TABLE 4-45 COMPARTMENT F - COCKPIT AREA COMPARTMENT - STARBOARD SIDE (SHEET 11 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	ALQ RCVR-X'mitter (Repeat Mode Select-GND or Repeat GND Test Capability	.100	----	----	TEL 715	GPMS	1A	——	06D11	GND/Open (Enable Driver)
2	ALQ-100 Receiver X'mitter	10	115V, 10A	6.5	TEL 700	ØA	1A	F1	05Q11	Hybrid Power Controller
3	ALQ-100 Receiver X'mitter	10	115V, 10A	6.5	TEL 701	ØB	1A	F1	05Q12	Hybrid Power Controller
4	ALQ-100 Receiver X'mitter	10	115V, 10A	6.5	TEL 702	ØC	1A	F1	05Q13	Hybrid Power Controller

TABLE 4-45 COMPARTMENT G - COCKPIT AREA COMPARTMENT - PORT SIDE AFT (SHEET 12 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Roll Computer Mach Trim	.5	28V, 2A	1.3	UCL 011	DC	1	G4	01Q22	
2	External Pwr Contactor & Pitch Comp	---	---	---	DHL 099	GPMS	1	----	04D14	Enable Drive
3	Roll Computer	----	----	---	DHL 100	GPMS	1	----	04D15	Enable Drive
4	Roll Computer	----	----	---	GHL 101	GPMS	1	----	04D16	Enable Drive
5	Roll Computer	1.5	28V, 2A	1.8	UCL 300	DC	1	G4	01Q23	
6	Roll Computer (Wing Sweep 57° Signal)	----	----	----	GEL 302	GPMS	1	----	04D17	Enable Drive
7	Roll Computer (Flaps 25° Down Signal)	----	----	----	CGL 303	GPMS	1	----	04D18	Enable Drive
8	Roll Computer (DLC Engage Signal)	----	----	----	TML 304	GPMS	1	----	04D19	Enable Drive
9	Roll Computer (Master Reset Signal)	----	----	----	UCL 309	GPMS	1	----	04D20	Enable Drive
10	Roll Computer (Ground Roll Braking Signal)	----	----	----	UCL 311	GPMS	1	----	04D21	Enable Drive
11	Roll Computer (Inboard Spoilers 18° Signal)	----	----	----	UCL 312	GPMS	1	----	04D22	Enable Drive
12	AC Power Contactor Assy	----	----	----	CKL 103	GPMS	2	----	04D23	Enable Drive
13	L. Air Inlet Control Programmer	.5	115V, 2A	1.6	KAL 029	ØC	4	G2	01Q24	
14	LPRF Processor (ETI)	.25	115V, 2A	1.2	DTL 732	ØA	4A	G1	01Q25	
15	Doppler Processor (ETI)	.25	115V, 2A	1.2	DTL 744	ØA	4A	G1	01Q26	
16	Doppler Filter (ETI)	.25	115V, 2A	1.2	DTL 745	ØA	4A	G1	01Q27	
17	Computer Signal Data Converter (CSDC)	.5	115V, 2A	1.6	RUL 055	ØB	8	G3	01Q28	
18	Computer Signal Data Converter	----	----	----	SXL 537	GPMS	10	----	04D24	Enable Drive
19	Computer Signal Data Converter	----	----	----	SXL 398	GPMS	10	----	04D25	Enable Drive
20	Computer Signal Data Converter	2	28V, 2A	2.0	UCL 065	DC	13	G3	01Q29	
21	Computer Signal Data Converter	1	115V, 2A	2.5	UCL 066	ØA	13	G2	01Q30	
22	Computer Signal Data Converter	1	115V, 2A	2.5	UCL 066	ØB	13	G3	01Q31	
23	Computer Signal Data Converter	1	115V, 2A	2.5	UCL 066	ØC	13	G2	01Q32	
24	Computer Signal Data Converter	2	28V, 2A	2.0	UCL 076	DC	14	G3	01Q33	
25	Roll SAS Computer (CSDC)	.5	115V, 2A	1.6	UCL 017	ØB	1	G3	01Q34	115V/26V X'former Load
26	Roll SAS (Interlock Return Signal)	----	----	----	AAL 328	GPMS	17	----	04D26	Relay Drive
27	CSDC - Pilot OBC Discrete	----	----	----	MJL 582	GPMS	43	----	04D27	Enable Drive
28	Roll Computer (Bit Arm - 28 VDC)	----	----	----	MJL 584	GPMS	43	----	04D28	Enable Drive

TABLE 4-45 COMPARTMENT G - COCKPIT AREA COMPARTMENT - PORT SIDE AFT (SHEET 13 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
29	L. Air Inlet Control Programmer	1	28V, 2A	1.5	KAL 535	DC	46	G4	01Q35	
30	AC R. Main Power Cont.	6A in rush .7A hold	28V, 10A	2.8	PUL 544	DC	46	G4	01Q36	
31	AC L. Main Power Cont.	6A in rush .7A hold	28V, 10A	2.8	PUL 547	DC	46	G4	01Q37	
32	Roll Computer (Power Supply)	.61	115V, 2A	1.6	UCL 008	ØA	1	G2	01Q38	
33	CSDC (Sync Ref)	.32	115V, 2A	1.2	RNL 067	ØA	14	G2	01Q39	
34	CSDC (Sync Ref)	.32	115V, 2A	1.2	RNL 067	ØB	14	G2	01Q40	
35	CSDC (Sync Ref)	.32	115V, 2A	1.2	RNL 067	ØC	14	G3	01Q41	
36	Power Supply AWW-4	1	115V, 2A	2.5	AAL 322	ØA	17	G1	01Q42	
37	Power Supply AWW-4	1	115V, 2A	2.5	AAL 322	ØB	17	G1	01Q43	
38	Power Supply AWW-4	1	115V, 2A	2.5	AAL 322	ØC	17	G1	01Q44	
39	Roll SAS Computer	.5	28V, 2A	1.3	UCL 016	DC	1	G4	01Q45	

TABLE 4-45 COMPARTMENT H & L - COCKPIT AREA COMPARTMENT STARBOARD SIDE AFT (SHEET 14 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Pitch Computer	.61	115V, 2A	1.7	UCL 003	ØA	1	H1	05Q14	
2	Pitch Computer (Auto Pitch Drive Trim)	.61	115V, 2A	1.7	UCL 004	ØA	1	H1	05Q15	
3	Yaw SAS Comp. "A" Power Supply	.61	115V, 2A	1.7	UCL 005	ØA	1	H1	05Q16	
4	Yaw SAS Comp. "B" Power Supply	.61	115V, 2A	1.7	UCL 006	ØA	1	H1	05Q17	
5	Yaw SAS Comp. "C" Power Supply	.61	115V, 2A	1.7	UCL 007	ØA	1	H1	05Q18	
6	Yaw SAS Comp. "A" Power Supply	1.5	28V, 2A	1.8	UCL 012	DC	1	L3	05Q19	
7	Yaw SAS Comp. "B" Power Supply	1.5	28V, 2A	1.8	UCL 013	DC	1	L3	05Q20	
8	Yaw Comp. Roll Authority	1.5	28V, 2A	1.8	UCL 014	DC	1	L4	05Q21	
9	Yaw SAS Comp. "M" Power Supply	1.5	28V, 2A	1.8	UCL 015	DC	1	L3	05Q22	
10	Pitch SAS Comp. (Wow Signal) Yaw SAS Comp. (Wow Signal)	.5	28V, 2A	1.3	UCL 016	DC	1	L3	05Q23	
11	Yaw Computer	---	---	---	UCL 099	GPMS	1	---	06D12	Enable Drive
12	Roll Computer	---	---	---	UCL 099	GPMS	1	---	06D13	
13	Pitch Computer	---	---	---	DHL 100	GPMS	1	---	06D14	Enable Drive
14	Yaw Computer	---	---	---	DHL 100	GPMS	1	---	06D15	
15	Pitch Computer	---	---	---	GHL 101	GPMS	1	---	06D16	Enable Drive
16	Pitch Computer	1.5	28V, 2A	1.8	UCL 301	DC	1	L3	05Q24	
17	Pitch Computer (Wing Sweep < 57° Signal)	---	---	---	GEL 302	GPMS	1	---	06D17	Enable Drive
18	Pitch Computer (Flaps ≥ 25°)	---	---	---	CGL 303	GPMS	1	---	06D18	Enable Driver
19	Pitch Computer (DLC Engage Signal)	---	---	---	TML 304	GPMS	1	---	06D19	Enable Driver
20	Roll, Pitch, Yaw Computers (Master Reset Signal)	---	---	---	UCL 309	GPMS	1	---	06D20	Enable Driver
21	Pitch Computer (Ground Roll Breaking Signal)	---	---	---	UCL 310	GPMS	1	---	06D21	Enable Driver
22	Pitch Computer - Inboard Spoilers (< 18° Signal)	---	---	---	UCL 313	GPMS	1	---	06D22	Enable Driver
23	Initiator Destruct Igniter (28 VDC Safe Enable)	---	---	---	TEL 703	GPMS	1A	---	06D23	Relay Driver
24	Initiator Destruct Igniter (28 VDC (Power Supply)	5A	28V, 5A	4.5	TEL 704	DC	1A	L4	05Q25	
25	Initiator Destruct Igniter	---	---	---	TEL 705	GPMS	1A	---	06D24	Open/GND

TABLE 4-45 COMPARTMENT H & L - COCKPIT AREA COMPARTMENT STARBOARD SIDE AFT (SHEET 15 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
26	Wing Flap Glove Vane Controller (Power Supply)	2A	28V, 2A	2.0	CGL 018	DC	2	L2	05Q26	
27	Wing Flap Glove Vane Controller (Power Supply)	.54	115V, 2A	1.6	CKL 020	ØC	2	H4	05Q27	
28	Wing Flap Glove Vane Controller Wing Sweep #1 (Power Supply)	.54	115V, 2A	1.6	CKL 021	ØC	2	H4	05Q28	
29	Wing Flap Glove Vane Controller Wing Sweep #2 (Power Supply)	.54	115V, 2A	1.6	CKL 022	ØC	2	H4	05Q29	
30	Rt. Air Inlet Control Programmer	.5	115V, 2A	1.6	KAL 030	ØA	4	H1	05Q30	
31	Regulator Power Supply	1.5	115V, 2A	3.2	TBL 729	ØA	4A	H2	05Q31	
32	Regulator Power Supply	1.5	115V, 2A	3.2	TBL 729	ØB	4A		05Q32	
33	Regulator Power Supply	1.5	115V, 2A	3.2	TBL 729	ØC	4A	H2	05Q33	
34	Regulated Power Supply (weight off main wheel signal)	.100	---	---	TBL 737	GPMS	4A	---	06D25	Enable Driver
35	Regulated Power Supply (main wheel intlk bypass 28V signal)	.100	---	---	TBL 738	GPMS	4A	---	06D26	Enable Driver
36	Regulated Power Supply (Antenna test signal 28 VDC	.100	---	---	TBL 739	GPMS	4A	---	06D27	Enable Driver
37	Semi-regulated Power Supply	5.4	115V, 10A	6.5	TBL 740	ØA	4A	H3	05Q34	Hybrid Power Controller
38	Semi-regulated Power Supply	5.4	115V, 10A	6.5	TBL 740	ØB	4A	H3	05Q35	Hybrid Power Controller
39	Semi-regulated Power Supply	5.4	115V, 10A	6.5	TBL 740	ØC	4A	H3	05Q36	Hybrid Power Controller
40	Mach Lever Cont. Unit (Power Supply #1)	.14	115V, 2A	1.2	QCL 032	ØB	6	H2	05Q37	
41	Mach Lever Cont. Unit (Power Supply #2)	.8	28V, 2A	2.3	QCL 033	ØC	6	H4	05Q38	
42	Mach Lever Cont. Unit (Power Conditioner)	1	28V, 2A	1.5	MJL 111	DC	6	L2	05Q39	
43	Emergency Ram Air Door Actuator Extend Leg	1.5	115V, 2A	3.2	HQL 198	ØC	32	H4	05Q40	
44	Emergency Ram Air Door Actuator Retract Leg	1.5	115V, 2A	3.2	HQL 199	ØC	32	H4	05Q41	
45	Bleed Air Flow Modulating Press. (Shut off valve reset)	1.5	28V, 2A	1.8	HPL 210	DC	32	L3	05Q42	
46	Bleed Air Flow Modulating Press. (Shut off Valve Enable)	1.5	28V, 2A	1.8	HPL 211	DC	32	L4	05Q43	

TABLE 4-45 COMPARTMENT H & L - COCKPIT AREA COMPARTMENT STARBOARD SIDE AFT (SHEET 16 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
47	WCS Coolent Pump	8.4	115V, 10A	6.5	HNL 175	ØA	34	L1	05Q44	Hybrid Pwr. Controller
48	WCS Coolent Pump	8.4	115V, 10A	6.5	HNL 175	ØB	34	L1	05Q45	Hybrid Pwr. Controller
49	WCS Coolent Pump	8.4	115V, 10A	6.5	HNL 175	ØC	34	L1	05Q46	Hybrid Pwr. Controller
50	WCS/Missle Controller (Power Supply)	3.	115V, 5A	5.4	HNL 176	ØC	34	H2	05Q47	
51	WCS/Missle Controller (Power Supply)	4.5	28V, 5A	4.5	HNL 178	DC	34	L2	05Q48	
52	WCS/Missle Controller (Power Supply)	4.5	28V, 5A	4.5	HNL 179	DC	34	L2	05Q49	
53	Aircraft Yaw Computer (Bit Arm-28VDC	---	---	---	MJL 583	GPMS	43	---	06D28	Enable Drive
54	Pitch Computer (Bit Arm-28 VDC)	---	---	---	MJL 584	GPMS	43	---	06D29	Enable Drive
55	Mach Lever Control (Test Initiate-On)	---	---	---	MJL 586	GPMS	43	---	06D30	Enable Drive
56	Air Inlet Control Programmer	1.	28V, 2A	1.5	KAL 536	DC	46	L4	05Q50	
57	L. Test Relay (P/O Volt. Reg. Cont.)	.250	---	---	PUL 548	GPMS	46	---	06D31	Enable Drive
58	AC Bus Controller ØA	100	115V,100A	10.	-	-	-	L5	06Q06	
59	AC Bus Controller ØB	100	11V,100A	10.	-	-	-	L6	06Q07	
60	AC Bus Controller ØC	100	11V,100A	10.	-	-	-	L7	06Q08	
61	DC Bus Controller	60	28V, 75A	10.	-	-	-	L8	06Q09	

TABLE 4-45 COMPARTMENT I - COCKPIT AREA COMPARTMENT PORT SIDE AFT CHEEK (SHEET 17 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Interference Blanker	.5	115V, 2A	1.6	TEL 706	ØB	1A	1	01Q46	
2	ILS Decoder	.24	115V, 2A	1.2	RAL 037	ØA	7	1	01Q47	
3	ILS Decoder	.24	115V, 2A	1.2	RAL 038	ØB	7	1	01Q48	
4	ILS Decoder	.24	115V, 2A	1.2	RAL 039	ØC	7	1	01Q49	
5	ILS Decoder	----	----	----	RAL 040	GPMS	7	----	04D29	Relay Drive
6	Amplifier/Relay Ass'y UHF Aux. Receiver	.9	28V, 2A	1.5	RDL 046	DC	8	4	01Q50	
7	Main UFH Antenna Switch	4.7	28V, 5A	4.3	RUL 041	DC	8	4	01Q51	
8	Amplifier/Relay	.34	115V, 2A	1.2	RUL 054	ØA	8	2	01Q52	
9	Interogator Switch Amp. Interogator Synchronizer	2.0	28V, 2A	2.0	SXL 057	DC	8	4	01Q53	
10	Transponder Receiver X'mitter	1.3	115V, 2A	2.8	SXL 060	ØB	10	3	01Q54	
11	Transponder Receiver X'mitter Test Set	1.5	28V, 2A	1.8	SXL 061	DC	10	4	01Q55	
12	Transponder Receiver X'mitter (Mode & Enable)	----	----	----	SXL 382	GPMS	10	----	04D30	Enable Drive
13	Transponder Receiver X'mitter (IFF Emergency Cont.)	----	----	----	SXL 537	GPMS	10	----	04D31	Enable Drive
14	Transponder Receiver X'mitter	----	----	----	SXL 538	GPMS	10	----	04D32	Enable Drive
15	Transponder Receiver X'mitter	----	----	----	SXL 398	GPMS	10	----	04D33	Enable Drive
16	Transponder Receiver X'mitter	----	----	----	SXL 399	GPMS	10	----	04D34	Enable Drive
17	Transponder Receiver X'mitter	----	----	----	SXL 400	GPMS	10	----	04D35	Enable Drive
18	Transponder Receiver X'mitter	1.0	28V, 2A	1.5	SXL 401	DC	10	4	01Q56	Enable Drive
19	Rate Gyro X'mitter	2.	28, 2A	2.0	FAL 402	DC	15	4	01Q57	
20	Bleed Air Leak Detector Cont. Unit	1.	115V, 2A	2.5	HNL 195	ØC	32	1	01Q58	
21	Bleed Air Leak Detector Cont. Unit	----	----	----	HNL 222	GPMS	32	- - -	04D36	Relay Drive
22	Taxi Landing Lights	3.9	115V, 5A	6.8	LRL 159	ØA	44	3	01Q59	
23	ADI Converter	1.0	115V, 2A	2.5	FEL 063	ØA	12	2	01Q60	
24	ADI Converter	1.0	115V, 2A	2.5	FEL 063	ØB	12	2	01Q61	
25	ADI Converter	1.0	115V, 2A	2.5	FEL 063	ØC	12	2	01Q62	
26	ADI Converter	.6	115V, 2A	1.6	FEL 064	ØA	12	2	01Q63	
27	ADI Converter	.6	115V, 2A	1.6	FEL 064	ØB	12	2	02Q01	
28	ADI Converter	.6	115V, 2A	1.6	FEL 064	ØC	12	1	02Q02	
29	Fuel Rate of Flow Power Supply	1.	115V, 2A	2.5	EHL 188	ØB	38	3	02Q03	

TABLE 4-45 COMPARTMENT I - COCKPIT AREA COMPARTMENT PORT SIDE AFT CHEEK (SHEET 18 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
30	AC Bus Controller ØA	100	115V,100A	10.		-	-	I5	02Q18	Remote Controlled Circuit Breaker
31	AC Bus Controller ØB	100	115V,100A	10.		-	-	I6	02Q19	Remote Controlled Circuit Breaker
32	AC Bus Controller ØC	100	115V,100A	10.		-	-	I7	02Q20	Remote Controlled Circuit Breaker
33	DC Bus Controller	60	28V, 75A	10.		-	-	I8	02Q21	Remote Controlled Circuit Breaker

TABLE 4-45 COMPARTMENT K & J - MID AND AFT FUSELAGE (SHEET 19 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Air Data Computer (Power Supply)	.9	115V, 2A	2.5	UCL 019	ØA	2	J3	02Q04	
2	Power Switching Unit	2.0	28V, 5A	3.0	AGL 126	DC	16	K1	05Q51	4A for 200MS; 2A Cont.
3	Power Switching Unit	2.0	28V, 5A	3.0	AGL 127	DC	16	K1	05Q52	4A for 200MS; 2A Cont.
4	Power Switching Unit	2.0	28V, 5A	3.0	AGL 128	DC	16	K1	05Q53	4A for 200MS; 2A Cont.
5	Power Switching Unit	.25	28V, 5A	2.1	AGL 129	DC	16	K1	05Q54	4A for 200MS; 25 Cont.
6	Power Switching Unit	2.0	28V, 5A	3.0	AGL 130	DC	16	K1	05Q55	4A for 200MS; 2A Cont.
7	Power Switching Unit	2.0	28V, 5A	3.0	AGL 131	DC	16	K1	05Q56	4A for 200MS; 2A Cont.
8	Power Switching Unit	2.0	28V, 5A	3.0	AGL 132	DC	16	K2	05Q57	4A for 200MS; 2A Cont.
9	Power Switching Unit	.25	28V, 5A	2.1	AGL 133	DC	16	K2	05Q58	4A for 200MS; .25 Cont.
10	Power Switching Unit	2.0	28V, 2A	2.0	AGL 134	DC	16	K2	05Q59	
11	Power Switching Unit	2.0	28V, 2A	2.0	AGL 135	DC	16	K2	05Q60	
12	Power Switching Unit	.340	28V, 2A	1.2	AGL 137	DC	16	K3	05Q61	
13	Power Switching Unit	4.5	28V, 5A	4.2	AGL 138	DC	16	K2	05Q62	
14	Power Switching Unit	4.5	28V, 5A	4.2	AGL 139	DC	16	K3	05Q63	
15	Power Switching Unit	.61	115V, 2A	1.7	AGL 142	ØA	16	J2	02Q05	
16	Power Switching Unit	.61	115V, 2A	1.7	AGL 143	ØA	16	J2	02Q06	
17	Power Switching Unit	.61	115V, 2A	1.7	AGL 144	ØB	16	J2	02Q07	
18	Power Switching Unit	.61	115V, 2A	1.7	AGL 145	ØB	16	J2	02Q08	
19	Power Switching Unit	.61	115V, 2A	1.7	AGL 146	ØC	16	J2	02Q09	
20	Power Switching Unit	.61	115V, 2A	1.7	AGL 147	ØC	16	J2	02Q10	
21	Power Switching Unit (Mech. Fusing Sta 1 & 8)	4.5	28V, 5A	4.2	AGL 397	DC	17	K3	06Q01	
22	Power Switching Unit (Gun Arm 28 VDC)	6.5	28V, 10A	5.8	ADL 334	DC	18	K2	06Q02	
23	Power Switching Unit	3.0	28V, 5A	3.5	AGL 338	DC	19	K3	06Q03	

TABLE 4-45 COMPARTMENT K & J (SHEET 20 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
24	Power Switching Unit	3.0	28, 5A	3.5	AGL 339	DC	19	K3	06Q04	
25	Cen. Air Data Comp. (Chnl #1 Pwr. Supply)	.87	115V, 2A	2.3	XAL 517	ØA	29	J3	02Q11	
26	Cen. Air Data Comp. (Chnl #1 Pwr. Supply)	.87	115V, 2A	2.3	XAL 517	ØB	29	J3	02Q12	
27	Cen. Air Data Comp. (Chnl #1 Pwr. Supply)	.87	115V, 2A	2.3	XAL 517	ØC	29	J3	02Q13	
28	Cen. Air Data Comp. (Chnl #2 Pwr. Supply) (Wing Sweep Back-up)	.87	115V, 2A	2.3	XAL 518	ØB	29	J3	02Q14	
29	Fail Monitor Light Driver (P/O ADC)	----	----	----	CKL 521	GPMS	29	----	06D32	Enable Driver
30	Fail Monitor Light Driver (P/O ADC)	----	----	----	CKL 522	GPMS	29	----	06D33	Enable Driver
31	Mode Logic Processor (P/O ADC)	----	----	----	CKL 523	GPMS	29	----	06D34	Enable Driver
32	Mode Logic Processor (P/O ALC)	----	----	----	CKL 524	GPMS	29	----	06D35	Enable Driver
33	Mode Logic Processor (P/O ADC)	----	----	----	CKL 525	GPMS	29	----	06D36	Enable Driver
34	Mode Logic Processor (P/O ADC)	----	----	----	CKL 526	GPMS	29	----	06D37	Enable Driver
35	Mode Logic Processor (P/O ADC)	----	----	----	CKL 527	GPMS	29	----	06D38	Enable Driver
36	Mode Logic Processor (P/O ADC)	----	----	----	CKL 528	GPMS	29	----	06D39	Enable Driver
37	Bleed Manifold Modulating Valve (Solenoid) Test Signal On (ADC)	3.0 .10	28V, 5A ----	3.5 ----	HCL 563 MJL 587	DC GPMS	43 43	K3 ----	06Q05, 06D40	Enable Driver
38	Processor	1.0	115V, 2A	2.5	TEL 062	ØA	11	J1	02Q15	
39	Processor	1.0	115V, 2A	2.5	TEL 062	ØB	11	J1	02Q16	
40	Processor	1.0	115V, 2A	2.5	TEL 062	ØC	11	J1	02Q17	
41	Data Link Transmission Line Switch	----	----	----	RUL 376	GPMS	27	----	04D37	

TABLE 4-45 REGION P - BOTTOM CENTERLINE OF AIRCRAFT AFT. STA. 395 (SHEET 21 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Sidewinder Launcher (STA 1A)	6.2	28V, 10A	5.6	AGL 340	DC	19	P16	08Q01	
2	Sidewinder Launcher (STA 1A)	2.0	115V, 2A	4.0	AGL 341	ØB	19	P14	02	
3	Sidewinder Launcher (STA 1B)	6.2	28V, 10A	5.6	AGL 342	DC	19	P17	03	
4	Sidewinder Launcher (STA 1B)	2.0	115V, 2A	4.0	AGL 343	ØB	19	P5	04	
5	Sidewinder Launcher (STA 8A)	6.2	28V, 10A	5.6	AGL 344	DC	19	P18	05	
6	Sidewinder Launcher (STA 8A)	2.0	115V, 2A	4.0	AGL 345	ØB	19	P2	06	
7	Sidewinder Launcher (STA 8B)	6.2	28V, 10A	5.6	AGL 346	DC	19	P19	07	
8	Sidewinder Launcher (STA 8B)	2.0	115V, 2A	4.0	AGL 347	ØC	19	P15	08	
9	AIM-7 Pwr. (STA 4F)	5.7	115V, 10A	6.5	AGL 348	ØA	20	P4	09	Hybrid Power Controller
10	AIM-7 Pwr. (STA 4F)	5.7	115V, 10A	6.5	AGL 349	ØB	20	P5	10	Hybrid Power Controller
11	AIM-7 Pwr. (STA 4F)	5.7	115V, 10A	6.5	AGL 350	ØC	20	P6	11	Hybrid Power Controller
12	AIM-7 Pwr. (STA 5F)	5.7	115V, 10A	6.5	AGL 351	ØA	20	P4	12	Hybrid Power Controller
13	AIM-7 Pwr. (STA 5F)	5.7	115V, 10A	6.5	AGL 352	ØB	20	P5	13	Hybrid Power Controller
14	AIM-7 Pwr. (STA 5F)	5.7	115V, 10A	6.5	AGL 353	ØC	20	P6	14	Hybrid Power Controller
15	AIM-7 Pwr. (STA 3F)	5.7	115V, 10A	6.5	AGL 354	ØA	20	P7	15	Hybrid Power Controller
16	AIM-7 Pwr. (STA 3F)	5.7	115V, 10A	6.5	AGL 355	ØB	20	P8	16	Hybrid Power Controller
17	AIM-7 Pwr. (STA 3F)	5.7	115V, 10A	6.5	AGL 356	ØC	20	P9	17	Hybrid Power Controller
18	AIM-7 Pwr. (STA 6F)	5.7	115V, 10A	6.5	AGL 357	ØA	20	P7	18	Hybrid Power Controller
19	AIM-7 Pwr. (STA 6F)	5.7	115V, 10A	6.5	AGL 358	ØB	20	P8	19	Hybrid Power Controller
20	AIM-7 Pwr. (STA 6F)	5.7	115V, 10A	6.5	AGL 359	ØC	20	P9	20	Hybrid Power Controller
21	AIM-7 Pwr. (STA 1B)	5.7	115V, 10A	6.5	AGL 360	ØA	20	P10	08Q21	Hybrid Power Controller

TABLE 4-45 REGION P - (SHEET 22 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
22	AIM-7 Pwr. (STA 1B)	5.7	115V, 10A	6.5	AGL 361	ØB	20	P12	08Q22	Hybrid Power Controller
23	AIM-7 Pwr. (STA 1B)	5.7	115V, 10A	6.5	AGL 362	ØC	20	P13	08Q23	Hybrid Power Controller
24	AIM-7 Pwr. (STA 8B)	5.7	115V, 10A	6.5	AGL 363	ØA	20	P10	08Q24	Hybrid Power Controller
25	AIM-7 Pwr. (STA 8B)	5.7	115V, 10A	6.5	AGL 364	ØB	20	P12	08Q25	Hybrid Power Controller
26	AIM-7 Pwr. (STA 8B)	5.7	115V, 10A	6.5	AGL 365	ØC	20	P13	08Q26	Hybrid Power Controller
27	Power Supply AWG-9	6.0	115V, 10A	6.5	AGL 366	ØA	20	P11	08Q27	Hybrid Power Controller
28	Power Supply AWG-9	6.0	115V, 10A	6.5	AGL 367	ØB	20	P14	08Q28	Hybrid Power Controller
29	Power Supply AWG-9	6.0	115V, 10A	6.5	AGL 368	ØC	20	P15	08Q29	Hybrid Power Controller
30	AIM-54 HTR Power (STA 5R)	7.0	115V, 10A	6.5	AGL 369	ØC	20	P1	08Q30	Hybrid Power Controller
31	AIM-54 HTR Power (STA 6R)	7.0	115V, 10A	6.5	AGL 370	ØC	20	P1	08Q31	Hybrid Power Controller
32	AIM-54 HTR Power (STA 3R)	7.0	115V, 10A	6.5	AGL 371	ØB	20	P2	08Q32	Hybrid Power Controller
33	AIM-54 HTR Power (STA 4R)	7.0	115V, 10A	6.5	AGL 372	ØB	20	P2	08Q33	Hybrid Power Controller
34	AIM-54 HTR Power (STA 1B)	7.0	115V, 10A	6.5	AGL 373	ØA	20	P3	08Q34	Hybrid Power Controller
35	AIM-54 HTR Power (STA 8B)	7.0	115V, 10A	6.5	AGL 374	ØA	20	P3	08Q35	Hybrid Power Controller
36	Battery Arm (STA 1B)	8.0	28V, 10A	6.6	AGL 383	DC	20	P18	08Q36	On 100 MS
37	Battery Arm (STA 3F)	8.0	28V, 10A	6.6	AGL 384	DC	20	P18	08Q37	On 100 MS
38	Battery Arm (STA 4F)	8.0	28V, 10A	6.6	AGL 385	DC	20	P18	08Q38	On 100 MS
39	Battery Arm (STA 5F)	8.0	28V, 10A	6.6	AGL 386	DC	20	P18	08Q39	On 100 MS
40	Battery Arm (STA 6F)	8.0	28V, 10A	6.6	AGL 387	DC	20	P16	08Q40	On 100 MS
41	Battery Arm (STA 8A)	8.0	28V, 10A	6.6	AGL 388	DC	20	P16	08Q41	On 100 MS

TABLE 4-45 REGION P (SHEET 23 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
42	Sparrow Motor Fire (STA 1B)	8.0	28V, 10A	6.6	AGL 389	DC	20	P17	08Q42	On 100 MS
43	Sparrow Motor Fire (STA 8B)	8.0	28V, 10A	6.6	AGL 390	DC	20	P17	08Q43	On 100 MS
44	Sparrow Motor Fire (STA 3F)	8.0	28V, 10A	6.6	AGL 391	DC	20	P17	08Q44	On 100 MS
45	Sparrow Motor Fire (STA 6F)	8.0	28V, 10A	6.6	AGL 392	DC	20	P19	08Q45	On 100 MS
46	Sparrow Motor Fire (STA 5F)	8.0	28V, 10A	6.6	AGL 393	DC	20	P19	08Q46	On 100 MS
47	Sparrow Motor Fire (STA 4F)	8.0	28V, 10A	6.6	AGL 394	DC	20	P20	08Q47	On 100 MS
48	AWG-9 Power Supply	3.0	28V, 5A	3.5	AGL 395	DC	20	P20	08Q48	
49	AIM-54 (STA 1B, 3R, 4R, 5R, 6R, 8B)	3.5	28V, 5A	3.8	AGL 396	DC	20	P20	08Q49	
50	Fuel Dump Shut-off Valve (Solenoid)	1.5	28V, 2A	1.8	QAL 237	DC	42	P20	08Q50	
51	Feed Tank Interconnect Valve (Solenoid)	1.5	28V, 2A	1.8	QAL 238	DC	42	P19	08Q51	
52	R. Vent Solenoid Valve and L. Vent Solenoid Valve	1.5	28V, 2A	1.8	QAL 239	DC	42	P16	08Q52	
53	Fuselage Motive Flow Solenoid Transfer Valve Forward Cell #2	1.5	28V, 2A	1.8	QAL 240	DC	42	P16	08Q53	
54	Fuselage Motive Flow Solenoid Transfer Valve Aft. Cell #5	1.5	28V, 2A	1.8	QAL 241	DC	42	p16	08Q54	
55	Motive Flow Isolation Valve Cell #2	1.5	28V, 2A	1.8	QAL 242	DC	42	P18	08Q55	
56	Crossfeed Solenoid Shut-off Pilot Valve	1.5	28V, 2A	1.8	QAL 244	DC	42	P17	08Q56	
57	Wing Motive Flow Solenoid Transfer Valve	1.5	28V, 2A	1.8	QAL 277	DC	42	P17	08Q57	

TABLE 4-45 REGION U - FLIGHT CONTROL TROUGH (SHEET 24 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Mach Trim Actuator	.61	115V, 2A	1.7	CFL 001	ØC	1	U1	11Q01	
2	Rudder Authority Control Actuator (Fixed Phase)	2.	115V, 2A	4.0	UCL 003	ØA	1	U3	02	
3	Spoiler Actuator Control Valve (Solenoid)	3.	28V, 5A	3.5	CKL 009	DC	1	U4	03	
4	Spoiler Actuator Control Valve (Solenoid)	3.	28V, 5A	3.5	CKL 010	DC	1	U4	04	
5	Rudder Trim Actuator	.67	115V, 2A	1.7	CJL 086	ØA	1	U3	05	
6	Rudder Trim Actuator	.67	115V, 2A	1.7	CJL 087	ØB	1	U2	06	
7	Rudder Trim Actuator	.67	115V, 2A	1.7	CJL 088	ØC	1	U1	07	
8	Rudder Trim Actuator (Clutch/Brake Solenoid)	1.5	28V, 2A	1.8	CJL 089	DC	1	U4	08	
9	Pitch & Mach Trim Actuator	.67	115V, 2A	1.7	CJL 090	ØA	1	U3	09	
10	Pitch & Mach Trim Actuator	.67	115V, 2A	1.7	CJL 091	ØB	1	U2	10	
11	Pitch & Mach Trim Actuator	.67	115V, 2A	1.7	CJL 092	ØC	1	U1	11	
12	Pitch & Mach Trim Actuator (Clutch/Brake Solenoid)	1.5	28V, 2A	1.8	CFL 093	DC	1	U4	12	
13	Pitch & Mach Trim Actuator (Clutch/Brake Solenoid)	1.5	28V, 2A	1.8	CFL 094	DC	1	U4	13	
14	Roll Trim Actuator (Fixed Phase)	.8	115V, 2A	2.3	CFL 305	ØA	1	U3	14	
15	Roll Trim Actuator (Fixed Phase)	.8	115V, 2A	2.3	CFL 306	ØB	1	U2	15	
16	Roll Trim Actuator (Fixed Phase)	.8	115V, 2A	2.3	CFL 307	ØC	1	U1	16	
17	Roll Trim Actuator (Clutch/Brake Solenoid)	1.5	28V, 2A	1.8	CFL 308	DC	1	U4	17	
18	20° Aux Flap/Wing Sweep Interlock Solenoid	1.5	28V, 2A	1.8	CKL 102	DC	2	U5	18	
19	Retract Rt. Aux. Flap Solenoid Retract Lf. Aux. Flap Solenoid Disable Flap-Slat Drive	3.0	28V, 5A	4.5	CKL 104	DC	2	U5	19	
20	Extend Rt. Aux. Flap Solenoid Extend Lf. Aux. Flap Solenoid	3.0	28V, 5A	4.5	CKL 105	DC	2	U5	20	
21	Dual Pressure Regulator and Shut-off Valve (Solenoid)	1.5	28V, 2A	1.8	HQL 214	DC	32	U5	21	
22	Solenoid By-pass Valve (P/O Cross Bleed Isolation By-pass and Check Valve)	1.5	28V, 2A	1.8	KKL 226	DC	40	U5	22	

TABLE 4-45 REGION U - FLIGHT CONTROL TROUGH (SHEET 25 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
23	Lf. Wing Position Light Bright Rt. Wing Position Light Bright	1.	115V, 2A	2.5	LNL 163	ØB	44	U2	11Q23	
24	Lf. Wing Position Light Dim Lt. Wing Position Light Dim	.25	115V, 2A	1.2	LNL 164	ØB	44	U2	11Q24	

TABLE 4-45 REGION V -- UPPER AFT END OF FUSELAGE (SHEET 26 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Wing Oversweep Actuator (Motor)	.67	115V, 2A	1.7	GEL 095	ØA	2	1	11Q25	
2	Wing Oversweep Actuator (Motor)	.67	115V, 2A	1.7	GEL 096	ØA	2	1	26	
3	Wing Oversweep Actuator (Motor)	.67	115V, 2A	1.7	GEL 097	ØB	2	2	27	
4	Clutch Brake Solenoid	1.5	28V, 2A	1.8	GEL 098	DC	2	3	28	
5	L. Horizontal Stabilizer Pos., X'mitter R. Horizontal Stabilizer Pos., X'mitter	.5 .5	115V, 2A 115V, 2A	1.6 1.6	QKL 031 QKL 031	ØA ØA	5 5	1	29	
6	Flight Control Back-up Module	3.0	28V, 5A	3.5	QSL 266	DC	35	3	30	
7	Flight Control Back-up Module Motor (High Speed Relay)	1.0	28V, 2A	1.5	QGL 267	DC	35	3	31	
8	Flight Control Back-up Module Motor (Low Speed Relay)	1.0	28V, 2A	1.5	QGL 268	DC	35	3	32	
9	Solenoid No. 1 Speed Brake Control Valve	1.5	28V, 2A	1.8	NAL 573	DC	43	3	33	
10	Solenoid No. 2 Speed Brake Control Valve	1.5	28V, 2A	1.8	NAL 574	DC	43	3	34	
11	Tail Position Light Bright	1.4	115V, 2A	3.2	LNL 161	ØB	44	2	35	
12	Tail Position Light Dim	.3	115V, 2A	1.2	LNL 162	ØB	44	2	36	
13	Flight Control Backup Module Motor	30PerØ	115V,50A	15	QGL269	ØA,ØB,ØC	35	V4	11Q37	Remote Controlled Circuit Breaker

TABLE 4-45 REGION Y - SPONSON REGION PORT & STARBOARD (SHEET 27 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD ON DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Left Sequencer Switch Fire Enable/GND Test	10.	28V, 10A	7.5	TEL 708	DC	1A	1 LF.	09Q01	
2	Right Sequencer Switch Fire Enable/GND Test	10.	28V, 10A	7.5	TEL 709	DC	1A	1 RT.	10Q01	
3	Flap, Control Surface, RT. & L. Rudder & Stabilizer Position X'mitter	.2	115V, 2A	1.2	CGL 025	ØB	2	3 LF.	09Q02	
4	L. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 034	ØA	6	3 LF.	09Q03	
5	R. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 034	ØA	6	3 RT.	10Q02	
6	L. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 035	ØB	6	3 LF.	09Q04	
7	R. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 035	ØB	6	3 RT.	10Q03	
8	L. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 036	ØC	6	3 LF.	09Q05	
9	R. Engine Turbine Temp. Limiter (Motor)	.8	115V, 2A	2.3	EBL 036	ØC	6	3 RT.	10Q04	
10	L. Engine Mid Cprsn By Pass Bleed Cont. (Solenoid)	3.0	28V, 5A	3.5	KCL 141	DC	16	2 LF.	09Q06	
11	R. Engine Mid Cprsn By Pass Bleed Cont. (Solenoid)	3.0	28V, 5A	3.5	KCL 140	DC	16	2 RT.	10Q05	
12	L. Bleed Air Shutoff Valve (Solenoid)	1.5	28V, 2A	1.8	HQL 213	DC	32	1 LF.	09Q07	
13	L. Bleed Air Shutoff Valve (Solenoid)	1.5	28V, 2A	1.8	HQL 212	DC	32	1 RT.	10Q06	
14	L. Engine MCB Bleed Solenoid	3.0	28V, 5A	3.5	KJL 193	DC	39	2 LF.	09Q08	
15	R. Engine MCB Bleed Solenoid	3.0	28V, 5A	3.5	KJL 194	DC	39	2 RT.	10Q07	
16	L. Engine Starter - Press. Regulator Shutoff Valve (Solenoid)	1.5	28V, 2A	1.8	KKL 225	DC	40	1 LF.	09Q09	
17	R. Engine Starter - Press. Regulator Shutoff Valve (Solenoid)	1.5	28V, 2A	1.8	KKL 224	DC	40	1 RT.	10Q08	
18	Ignition Control (P/O L. Eng. Ignition Termination X'former)	----	----	----	KKL 227	GPMS	40	----	06D41	Enable Drive
19	Ignition Control (P/O R. Eng. Ignition Termination X'former)	----	----	----	KKL 228	GPMS	40	----	06D42	Enable Drive
20	L. Engine Ejector Regulating Shutoff Valve (P/O Oil Cooler Ejector Sys. (Solenoid)	1.5	28V, 2A	1.8	KEL 232	DC	40	2 LF.	09Q10	
21	R. Engine Ejector Regulating Shutoff Valve (P/O Oil Cooler Ejector Sys. (Solenoid)	1.5	28V, 2A	1.8	KEL 233	DC	40	2 RT.	10Q09	

TABLE 4-45 REGION Y - SPONSON REGION PORT & STARBOARD (SHEET 28 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
22	L. Engine Idle Exhaust Nozzle (Solenoid)	1.5	28V, 2A	1.8	EJL 234	DC	40	1 LF.	09Q11	
23	R. Engine Idle Exhaust Nozzle (Solenoid)	1.5	28V, 2A	1.8	EJL 235	DC	40	2 RT.	10Q10	
24	Aux. Fuel Tank Press. Regulator (Solenoid)	1.5	28V, 2A	1.8	QAL 243	DC	42	2 LF.	09Q12	

TABLE 4-45 GLOVE RELAY AREA - STARBOARD SIDE (SHEET 29 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	ECM Control PNL - Power Supply	2	115V, 2A	4.0	TEL 707	ØB	1A	RG 2	07Q01	
2	CHAFF (Flare Dispense PNL)	.4	28V, 2A	1.2	TEL 710	DC	1A	RG 4	02	
3	ECM Control PNL	1.0	28V, 2A	1.5	TEL 713	DC	1A	RG 4	03	
4	Sweep Indicator - Power Supply	.17	115V, 2A	1.1	CKL 023	ØB	2	RG 2	04	
5	Angle of Attack F'lter	.14	115V, 2A	1.0	TLL 024	ØB	2	RG 2	05	
6	Angle of Attack Ind	.15	115V, 2A	1.0	FDL 110	ØB	3	RG 2	06	
7	DDI	.17	115V, 2A	1.1	RPL 716	ØA	3A	RG 1	07	
8	NFO Main-Data Link Control PNL Pilot Main-Data Link Control PNL	.8	28V, 2A	1.4	RPL 717	DC	3A	RG 4	08	
9	Computer Address, DDD (Motor Fan)	1.4	115V, 2A	3.1	TBL 727	ØA	4A	RG 1	09	
10	Computer Address, DDD (Motor Fan)	1.4	115V, 2A	3.1	TBL 727	ØB	4A	RG 2	10	
11	Computer Address, DDD (Motor Fan)	1.4	115V, 2A	3.1	TBL 727	ØC	4A	RG 1	11	
12	HSD Indicator	1.6	115V, 2A	3.2	TEL 062	ØA	9	RG 1	12	
13	ECM Display Indicator	1.6	115V, 2A	3.2	TEL 062	ØB	9	RG 2	13	
14	ECM Display Indicator	1.6	115V, 2A	3.2	TEL 062	ØC	9	RG 1	14	
15	NFO Caution Advisory Ind. Pilot Caution Advisory Ind.	9	28V, 10A	7.1	DUL 075	DC	14	RG 5	15	
16	Right Pitot Static Probe Heater	1.2	115V, 2A	2.8	HAL 078	ØB	15	RG 3	16	
17	Pilots Stand-By Attitude Indicator NFO Stand-By Attitude Indicator	.150	115V, 2A	1.0	FDL 533	ØB	15	RG 3	17	
18	Pilots Stand-By Attitude Indicator NFO Stand-By Attitude Indicator	.150	115V, 2A	1.0	FDL 534	ØA	15	RG 1	18	
19	Pilots BDHI NFO BDHI	.5	28V, 2A	1.2	RUL 403	DC	15	RG 4	19	
20	Air Conditioner Control Panel (Power Supply)	1	28V, 2A	1.2	HNL 216	DC	32	RG 4	20	
21	NFO Seat Bucket Height Adjustment (Motor-Up)	1	115V, 2A	2.5	WFL 559	ØB	43	RG 3	21	
22	Liquid Quantity Indicator	.10	115V, 2A	1.0	XAL 561	ØB	43	RG 3	22	
23	Radar Warning System	.5	28V, 2A	1.3	SWL 566	DC	43	RG 4	23	
24	28 VDC Input & Caution, (P/O L. Alarm Control)	2	28V, 2A	2.0	PAL 571	DC	43	RG 5	07Q24	

TABLE 4-45 GLOVE RELAY AREA - STARBOARD SIDE (SHEET 30 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
25	28 VDC Input & Caution (P/O R. Alarm Control)	2	28V, 2A	2.0	PAL 572	DC	43	RG5	07Q25	
26	NFO Seat Bucket Height Adjustment (Motor-Down)	1	115V, 2A	2.5	WFL 588	ØB	43	RG3	26	
27	Pilots Seat Bucket Height Adjustment (Motor-Up)	1	115V, 2A	2.5	WFL 589	ØB	43	RG3	27	
28	Pilots Seat Bucket Height Adjustment (Motor-Down)	1	115V, 2A	2.5	WFL 590	ØB	43	RG3	28	
29	Caution & Advisory Pool (Lights & Logic)	4.2	28V, 5A	4.1	VAL 529	DC	46	RG5	29	
30	RT & LF Alarm Controls	.5	28V, 2A	1.3	FPL 565	DC	43	RG5	30	
31	Shutoff Valve Solenoid (P/O Primary Heat Exchanger Fan and Modulating Shutoff Valve	1.5	28V, 2A	1.8	HNL 219	DC	32	RG6	31	
32	Missile Coolant Pump Motor	5.9	115V, 10A	6.5	HNL 177	ØA	34	RG7	32	Hybrid Power Controller
33	Missile Coolant Pump Motor	5.9	115V, 10A	6.5	HNL 177	ØB	34	RG7	33	Hybrid Power Controller
34	Missile Coolant Pump Motor	5.9	115V, 10A	6.5	HNL 177	ØC	34	RG7	34	Hybrid Power Controller
35	Flt. Transfer Pump Shutoff Valve	1.5	28V, 2A	1.8	QSL 263	DC	35	RG6	35	
36	Rt. Upper & Lower Supp. Light (Dim)	.3	115V, 2A	1.2	LNL 165	ØA	44	RG8	36	
37	Rt. Upper & Lower Supp. Light (Bright)	1.3	115V, 2A	2.8	LNL 166	ØA	44	RG8	37	
38	Rt. Wing Seal Pump Valve	.5	28V, 2A	1.3	CKL 542	DC	46	RG6	07Q38	

TABLE 4-45 GLOVE RELAY AREA - PORT SIDE (SHEET 31 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
1	Wheel-Flaps Position Indicator Flaps Flaps Position Indicator Control Surface Indicator	.22	115V, 2A	1.2	CGL 025	ØC	2	LG 4	03Q01	
2	TID (Motor-Fan), & ETI	.5	115V, 2A	1.3	AGL 741	ØA	5A	LG 1	02	
3	TID (Motor-Fan), & ETI	.5	115V, 2A	1.3	AGL 741	ØB	5A	LG 2	03	
4	TID (Motor-Fan), & ETI	.5	115V, 2A	1.3	AGL 741	ØC	5A	LG 4	04	
5	Sensor Control PNL (ETI Driver)	.250	115V, 2A	1.2	DTL 742	ØA	5A	LG 1	05	
6	Mission Recorder (Camera Motor)	.5	115V, 2A	1.6	SRL 743	ØA	5A	LG 1	06	
7	DDD, TID & Mission Recorder	3.	28, 5A	4.5	THL 750	DC	5A	LG 5	07	
8	Pilots ICS Control Panel	.72	28V, 2A	1.4	RZL 044	DC	8	LG 5	08	
9	NFO ICS Control Panel	.72	28V, 2A	1.4	RZL 045	DC	8	LG 5	09	
10	Left Fuselage Light	1.2	115V, 2A	2.8	HAL 079	ØB	15	LG 2	10	
11	Radar Altimeter	2.	28V, 2A	2.0	SAL 080	DC	15	LG 5	11	
12	Radar Altimeter	.39	115V, 2A	1.4	SAL 081	ØB	15	LG 2	12	
13	PMS Relay Assy'	.4	115V, 2A	1.4	RNL 085	ØA	15	LG 1	13	
14	Pilot Comm/Nav CMD PNL ARN-84 TACAN RCVR Xmitter	.5	28V, 2A	1.2	RUL 403	DC	15	LG 5	14	
15	ACM PNL	2.	28V, 2A	2.0	AGL 136	DC	16	LG 5	15	
16	AWG-15 (28 VDC)	2	28V, 2A	2.0	AGL 152	DC	17	LG 5	16	
17	Armament PNL	.6	115V, 2A	1.7	AGL 142	ØA	17	LG 1	17	
18	No. 2 UHF Radio PNL (28 VDC)	1.5	28V, 2A	1.8	RUL 375	DC	27	LG 5	18	
19	Pilots Servo Pneumatic Altimeter(Pwr.Supply) NFO Servo Pneumatic Altimeter(Pwr. Supply)	2.	28V, 2A	2.0	FKL 519	DC	29	LG 5	19	
20	Pilots Servo Pneumatic Altimeter (Solenoid & Servo Motor) NFO Servo Pneumatic Altimeter (Solenoid & Servo Motor) Pilots Mach-Airspeed Indicator	.44	115V, 2A	1.4	FKL 520	ØB	29	LG 2	20	
21	Lock Solenoid (P/O Landing Gear Handle)	1.5	28V, 2A	1.8	GDL 278	DC	30	LG 5	21	
22	Weapons Control Sys. AN/AWG-9	3.0	28V, 5A	3.5	QGL 270	DC	35	LG 5	22	
23	Hydrsulic Press. X'mitter (P/O Hyd. Press. Indicator)	.150	115V, 2A	1.2	DHL 271	ØB	35	LG 2	03Q23	

TABLE 4-45 GLOVE RELAY AREA - PORT SIDE (SHEET 32 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
24	Hydraulic Press. X'mitter (P/O Hyd. Press. Indicator)	.150	115V, 2A	1.2	DHL 272	ØB	35	LG 2	03Q24	
25	Fuel Flow Indicator	.2	115V, 2A	1.2	EHL 183	ØB	38	LG 3	25	
26	RMP Indicator (LF. Channel)	.2	115V, 2A	1.2	EHL 184	ØB	38	LG 3	26	
27	RMP Indicator (RT. Channel)	.2	115V, 2A	1.2	EHL 185	ØB	38	LG 3	27	
28	TIT Indicator (LF. Channel)	.2	115V, 2A	1.2	ELL 186	ØB	38	LG 3	28	
29	TIT Indicator (RT. Channel)	.2	115V, 2A	1.2	ELL 187	ØB	38	LG 3	29	
30	Fuel Flow Indicator	.2	115V, 2A	1.2	EHL 188	ØB	38	LG 3	30	
31	Utility/Map Lights X'former	.7	115V, 2A	1.7	LHL 509	ØC	45	LG 4	31	
32	ACM PNL Light Control (Channel 2)	1.	115V, 2A	2.5	LHL 510	ØC	45	LG 4	32	
33	UHF Antenna	.5	115V, 2A	1.6	RUL 055	ØA	8	LG 7	33	
34	Pilots BDHI	.5	115V, 2A	1.6	FFL 378	ØA	15	LG 7	34	115V/26V X'former load
35	RT. Engine Exhaust Nozzle Pos. Ind.	.100	115V, 2A	1.2	EPL 191	ØA	38	LG 7	35	115V/26V X'former load
36	LF. Engine Exhaust Nozzle Pos. Ind.	.100	115V, 2A	1.2	EPL 192	ØA	38	LG 7	36	115V/26V X'former
37	ACM PNL	.5	115V, 2A	1.6	LHL 515	ØA	45	LG 7	37	115V/26V X'former load
38	ACM PNL	.5	115V, 2A	1.6	LHL 516	ØA	45	LG 7	38	115V/26V X'former load
39	High Approach Lights	.5	115V, 2A	1.6	LAL 107	ØA	3	LG 8	39	115V/26V X'former load
40	Low Approach Lights	.5	115V, 2A	1.6	LAL 108	ØA	3	LG 8	40	115V/26V X'former load
41	Nur. Approach Lights	.5	115V, 2A	1.6	LAL 109	ØA	3	LG 8	41	115V/26V X'former load
42	Shutoff Valve Solenoid P/O Secondary Heat Exchanger Turbofan Shutoff Valve	1.5	28V, 2A	1.8	HNL 219	DC	32	LG 9	42	
43	Combined Transfer Pump Shutoff Valve	1.5	28V, 2A	1.8	QSL 262	DC	35	LG 9	43	
44	Normal Isolation Shutoff Valve	1.5	28V, 2A	1.8	QSL 264	DC	35	LG 9	44	
45	Flt/GND Test Shutoff Valve (Combined Sys. Press. Module)	1.5	28V, 2A	1.8	QSL 265	DC	35	LG 9	03Q45	

TABLE 4-45 GLOVE RELAY AREA - PORT SIDE (SHEET 33 OF 33)

ITEM	LOAD DESCRIPTION	LOAD CURRENT (AMPS)	CONTROLLER RATING (VOLTS, AMPS)	CONTROLLER DISSIPATION (WATTS)	CONTROLLER IDENTIFICATION	LOAD OR DATA BUS	REF. FIG. NO.	CONTROLLER MODULE NO.	OPERATIONAL ADDRESS	REMARKS
46	Motor Generator Solenoid Control Valve	1.5	28V, 2A	1.8	MJL 585	DC	43	LG9	03Q46	
47	LF Upper & Lower Supp. Light Dim	.3	115V, 2A	1.2	LNL 165	ØA	44	LG10	47	
48	LF Upper & Lower Supp. Light Bright	1.3	115V, 2A	2.8	LNL 166	ØA	44	LG 10	48	
49	LF Wing Seal Pump Valve	.5	28V, 2A	1.3	CKL 542	DC	46	LG 9	49	
50	Spoiler/High-Lift Back-up Module Motor	30 per Ø	115V, 50A	15.	CGL 181	ØA, ØB, ØC	37	LG 11	03Q50	Remote Controller Circuit Breaker

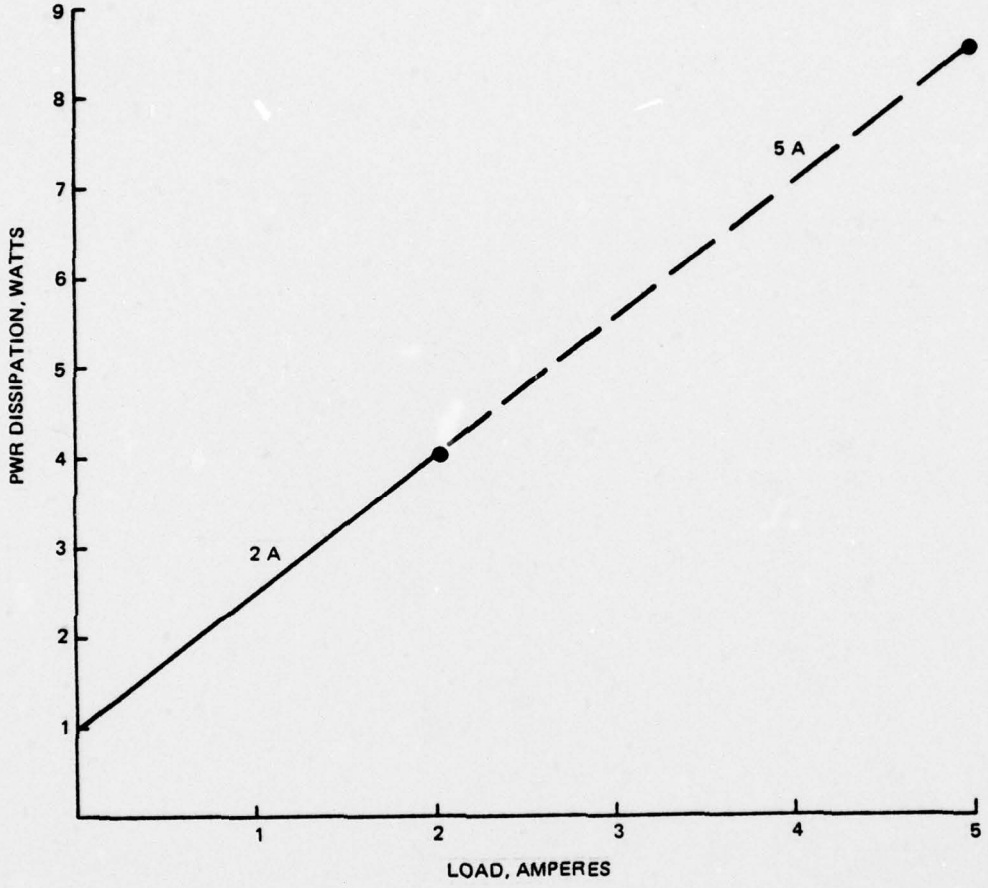


Figure 4-105. A-C Power Controllers - Power Dissipation vs Load

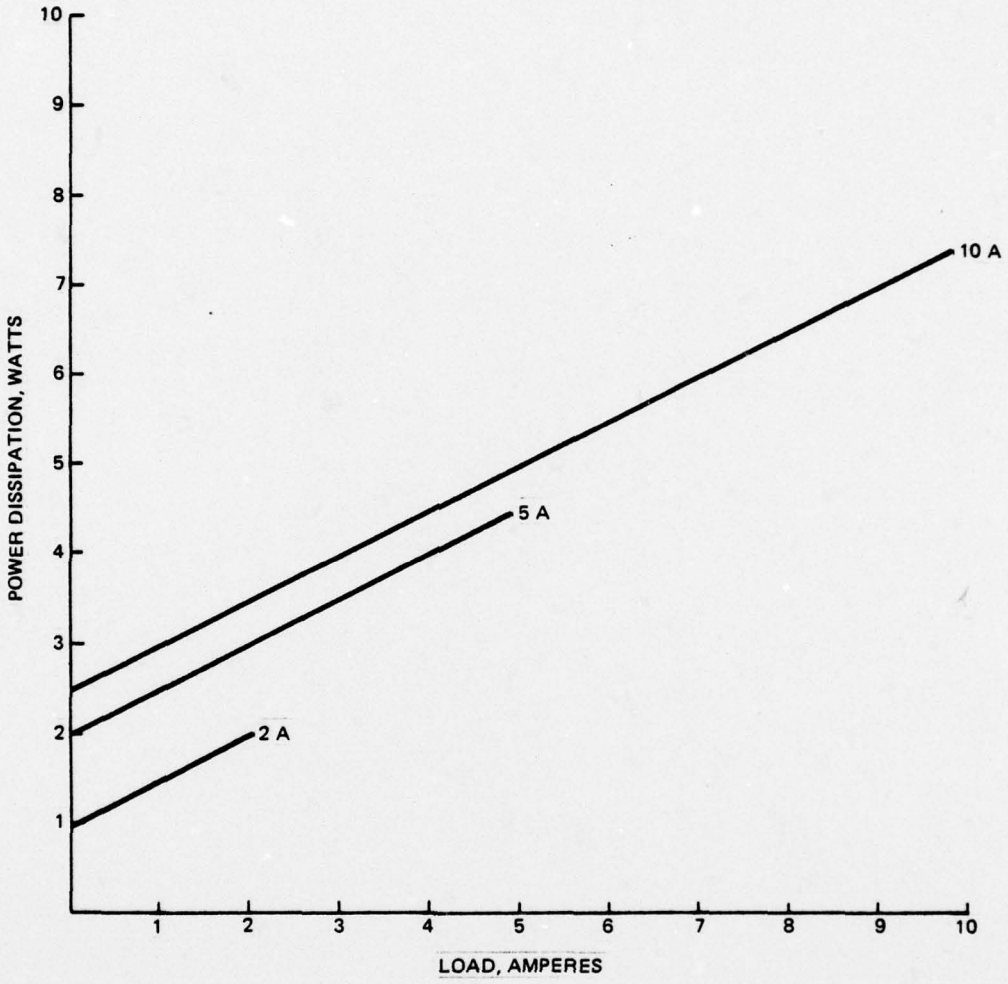


Figure 4-106. D-C Power Controllers - Power Dissipation vs Load

TABLE 4-46. POWER DISSIPATION/HEAT SINK TEMPERATURES

Compartment	Power Dissipation Watts/Heat Sink Temp, °C by Module No.																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	
A	W °C	18.2 58	19.5 59	19.5 59																		57
B	W °C	18.8 63	17.8 62	18.3 62	10.5 54	18.7 63	19.5 64															105
C	W °C	20.4 64																				20
D	W °C	16.1 67	16.5 67	14.9 67	10.6 61	12.1 63	8.3 59	12.4 63	16.4 67													105
E	W °C	6.5 81																				6
F	W °C	19.5 83																				20
G	W °C	11.1 65	10.6 64	10.9 65	11.5 65																	43
H	W °C	10.1 70	16.2 77	19.5 80	13.5 74																	49
I	W °C	9.3 70	11.9 77	12.1 80	13.1 74	10 72	10 72	10 72	10 72													85
J	W °C	7.5 82	10.2 85	11.7 86																		30
K	W °C	18.0 92	19.1 93	20.1 95																		57
L	W °C	19.5 80	12.5 72	10.3 70	9.6 70	10 71	10 71	10 71	10 72													91
LG	W °C	7.2 81	9.3 85	7.2 81	6.8 80	12.5 91	11.1 90	8.8 84	4.8 78	10.8 87	4.0 77	15 95										97
RG	W °C	14.7 93	11.4 90	14.8 93	8.1 83	16.5 95	4.9 71	19.5 99	4.0 77													95
P	W °C	13.0 90	17.0 96	13.0 90	13.0 90	17.0 96	13.0 90	13.0 90	13.0 90	13.0 90	13.0 90	6.5 81	13.0 90	13.0 90	10.5 86	10.5 86	5.4 79	9.2 84	7.4 82	7.4 82	9.1 84	230
U	W °C	7.4 82	9.4 85	9.7 85	14.2 92	14.4 92																55
V	W °C	6.6 81	6.1 80	11.9 88	15 85																	39
YLF	W °C	12.9 90	10.6 87	8.1 83																		31
YRF	W °C	11.1 87	10.2 87	6.9 81																		28

Total 103 Modules

1243 Watts

Figure 4-107 presents a layout drawing of the installation of the load power and bus controllers tabulated in Tables 4-45 and 4-46.

4.2.10 CONTROL GROUP OK171 INSTALLATION AND THERMAL ANALYSIS

The goal of this effort was to locate the control group components as close as possible to their respective interfaces and perform this installation without repositioning existing WRA's or severely impacting the ECS. These goals are realistic, and as the subsequent discussion will demonstrate they can be achieved.

Based on presently available hardware, plus anticipated future miniaturization of components and reduction in circuit complexity, the following OK171 component parameters were used. These are the result of vendor solicited information as well as in-house estimates based upon actual hardware designs.

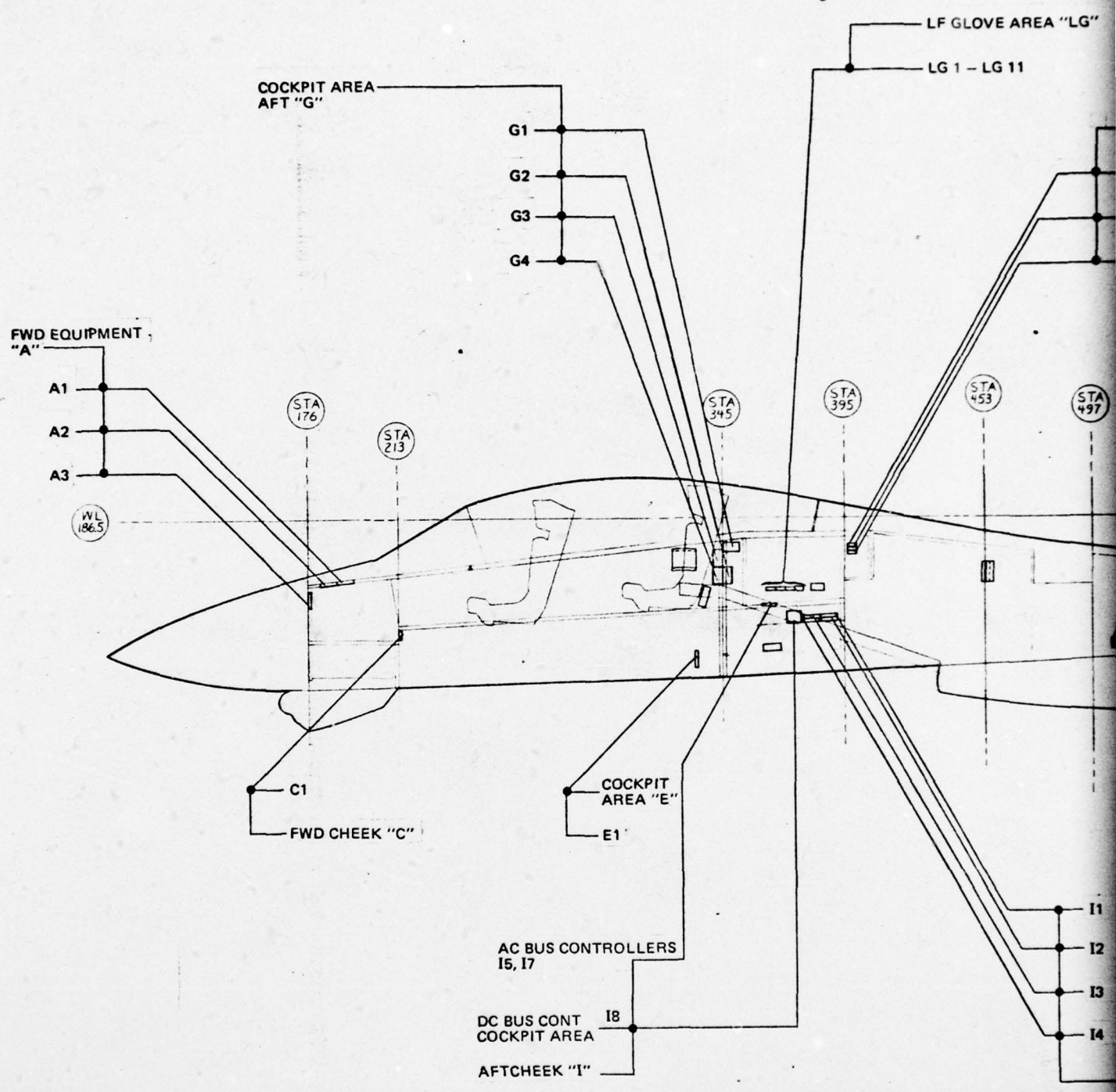
Component	LWH Dimensions, in.	Weight, lb	Dissipation, w
MUX	8x5x3 (5x4x3)	3.3 (2.5)	13 (3)
DEMUX	8x5x3 (5x4x3)	5.0 (4.0)	13 (10)
MUX/DEMUX	8x5.5x3	7.5 (7.0)	13
GPMS	8x5.5x3	5.0	13
PROCESSOR	20.6x5.4x3.6	18.0 (8.0)	75 (15)
CCDP	10x9x3	66.0 (5.0)	5

"Worst case" envelope dimensions, weight, and power dissipation were used for the MUX and DEMUX. These figures were used to ensure physical fit and thermal survival. The projected circa 1980 parameters are indicated in brackets, where applicable. The CCDP parameter estimates are based upon utilization of the SOSTEL specified unit driven by a MUX/DEMUX. This MUX/DEMUX is not included in the foregoing CCDP figures, but is included in the total system summary.

An interactive alphanumeric-incandescent display would require 49 w (typical; includes the microprocessor chip set, bus interface, displays, etc) and does not require a MUX/DMUX. It would weigh 10 lb, and occupy a volume 8x6x7 in.

MODULE	COMPART-MENT	LOCATION	STATION
A1 - A3	A	FORWARD EQUIPMENT COMPARTMENT – PORT SIDE	176-213
B1 - B6	B	FORWARD EQUIPMENT COMPARTMENT – STARBOARD SIDE	176-213
C1	C	COCKPIT AREA COMPARMENT – PORT SIDE FWD CHEEK	213-241
D1 - D8	D	COCKPIT AREA COMPARTMENT – STARBOARD SIDE FWD CHEEK	213-292
E1	E	COCKPIT AREA COMPARTMENT – PORT SIDE	345
F1	F	COCKPIT AREA COMPARTMENT – STARBOARD SIDE	292-345
G1 - G4	G	COCKPIT AREA COMPARTMENT – PORT SIDE, AFT	345-395
H1 - H4	H	COCKPIT AREA COMPARTMENT – STARBOARD SIDE, AFT	345-395
I1 - I8	I	COCKPIT AREA COMPARTMENT – PORT SIDE, AFT CHEEK	345-395
J1 - J3	J	MID AND AFT FUSELAGE COMPARTMENT – PORT SIDE	395-406
K1 - K3	K	MID AND AFT FUSELAGE COMPARTMENT – STARBOARD SIDE	395-406
L1 - L8	L	ECS COMPARTMENT – STARBOARD SIDE	345-395
LG1 - LG11	GLOVE AREA	PORT GLOVE AREA	345-395
RG1 - RG8	GLOVE AREA	STARBOARD GLOVE AREA	345-395
P1 – P20	P	BOTTOM FUSELAGE U1	447-AFT
U1 - U5	U	FLIGHT CONTROL TROUGH	529-AFT
V1 - V4	V	UPPER AFT END OF FUSELAGE	702-AFT
YLF1 - YLF3	Y	PORT SPONSON	640-AFT
YRT1 - YRT3	Y	STARBOARD SPONSON	640-AFT

Figure 4-107. Load Power and Bus Controller Module Compartment Installation Layout (Sheet 1 of 5)


LF GLOVE AREA "LG"
LG 1 – LG 11
COCKPIT AREA AFT "G"
G1
G2
G3
G4
FWD EQUIPMENT "A"
A1
A2
A3
STA 176
STA 213
STA 345
STA 395
STA 453
STA 497
WL 186.5
C1
FWD CHEEK "C"
COCKPIT AREA "E"
E1
AC BUS CONTROLLERS I5, I7
DC BUS CONT COCKPIT AREA
I8
AFTCHEEK "I"
I1
I2
I3
I4

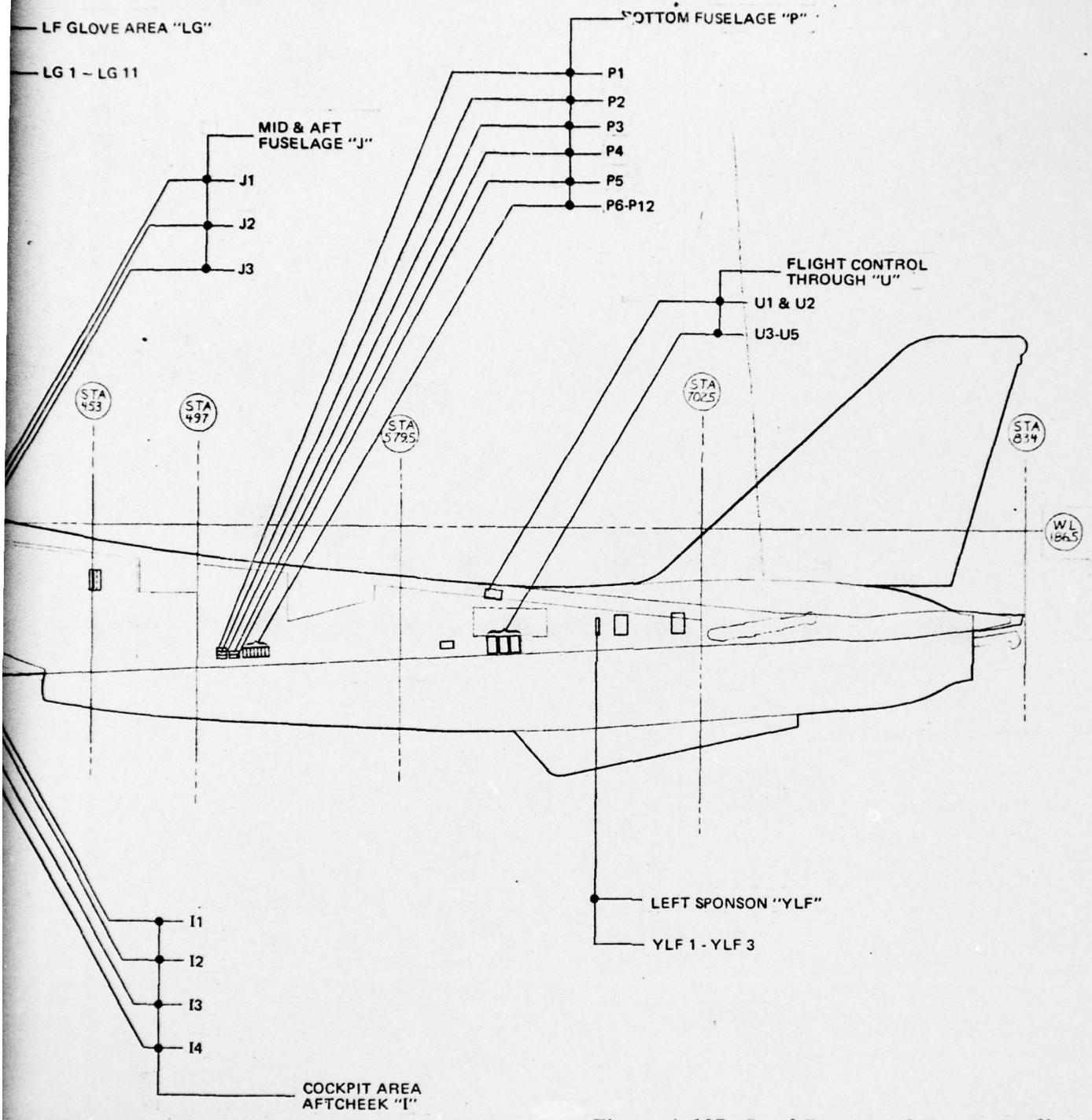


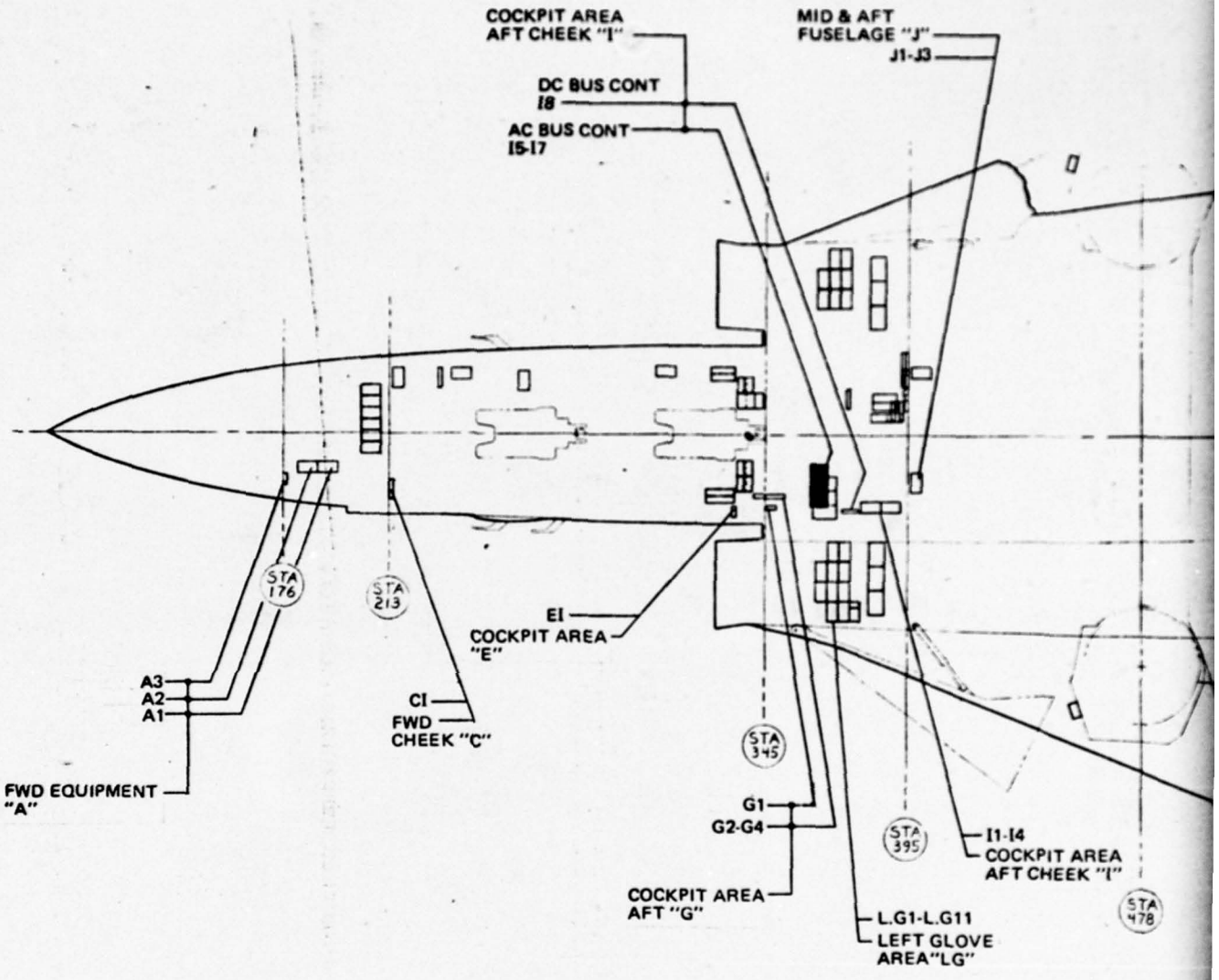
Figure 4-107. Load Power and Bus Controller Module Compartment Installation Layout - Port Elevation (Sheet 2 of 5)

AD-A047 859 GRUMMAN AEROSPACE CORP BETHPAGE N Y F/G 9/3
ADVANCED AIRCRAFT ELECTRICAL SYSTEM (AAES). DEFINITION AND PROT--ETC(U)
JUL 76 G COTTER, H SIEGEL, P PISANI N62269-75-C-0392
UNCLASSIFIED NADC-76194-30-VOL-1 NL

5 OF 5
AD
A047859



END
DATE FILMED
1-78
DDC



U1 & U2

U3-U5

FLIGHT CONTROL
THROUGH "U"

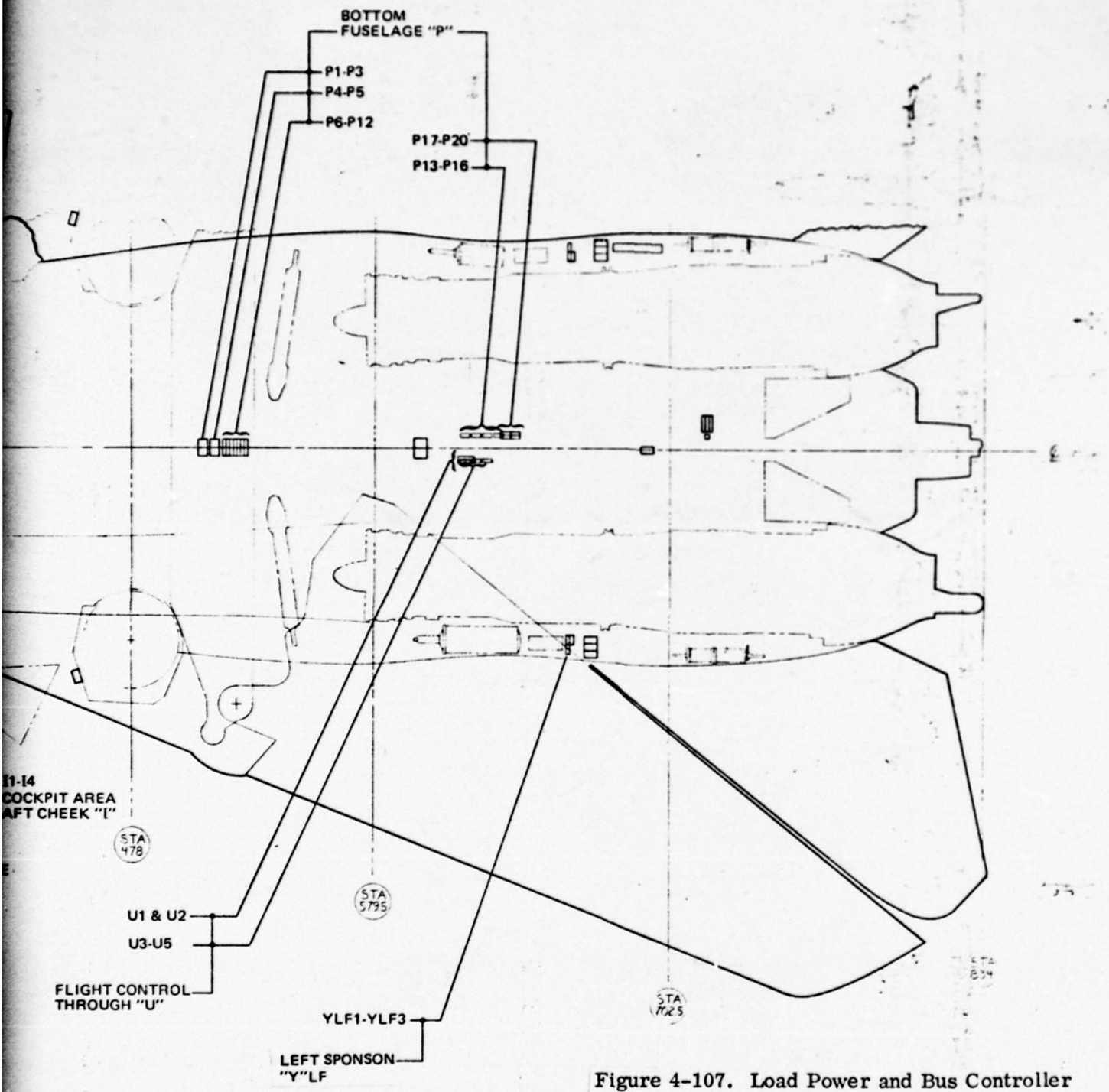
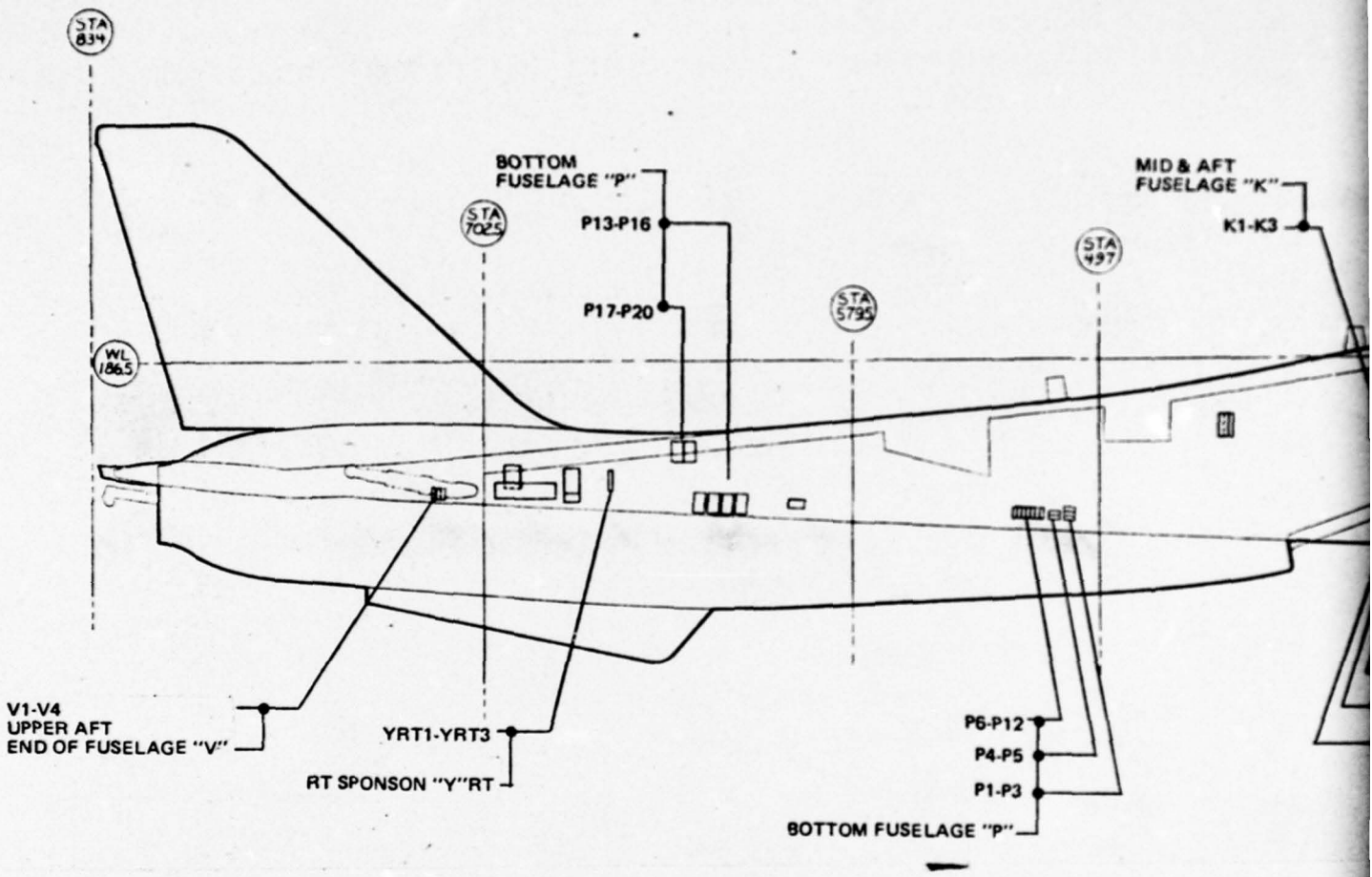


Figure 4-107. Load Power and Bus Controller Module Compartment Location - Port Plan (Sheet 3 of 5)


STA 834
BOTTOM FUSELAGE "P"
STA 702.5
P13-P16
P17-P20
STA 579.5
STA 497
MID & AFT FUSELAGE "K"
K1-K3
WL 186.5
V1-V4
UPPER AFT
END OF FUSELAGE "V"
YRT1-YRT3
RT SPONSON "Y"RT
P6-P12
P4-P5
P1-P3
BOTTOM FUSELAGE "P"

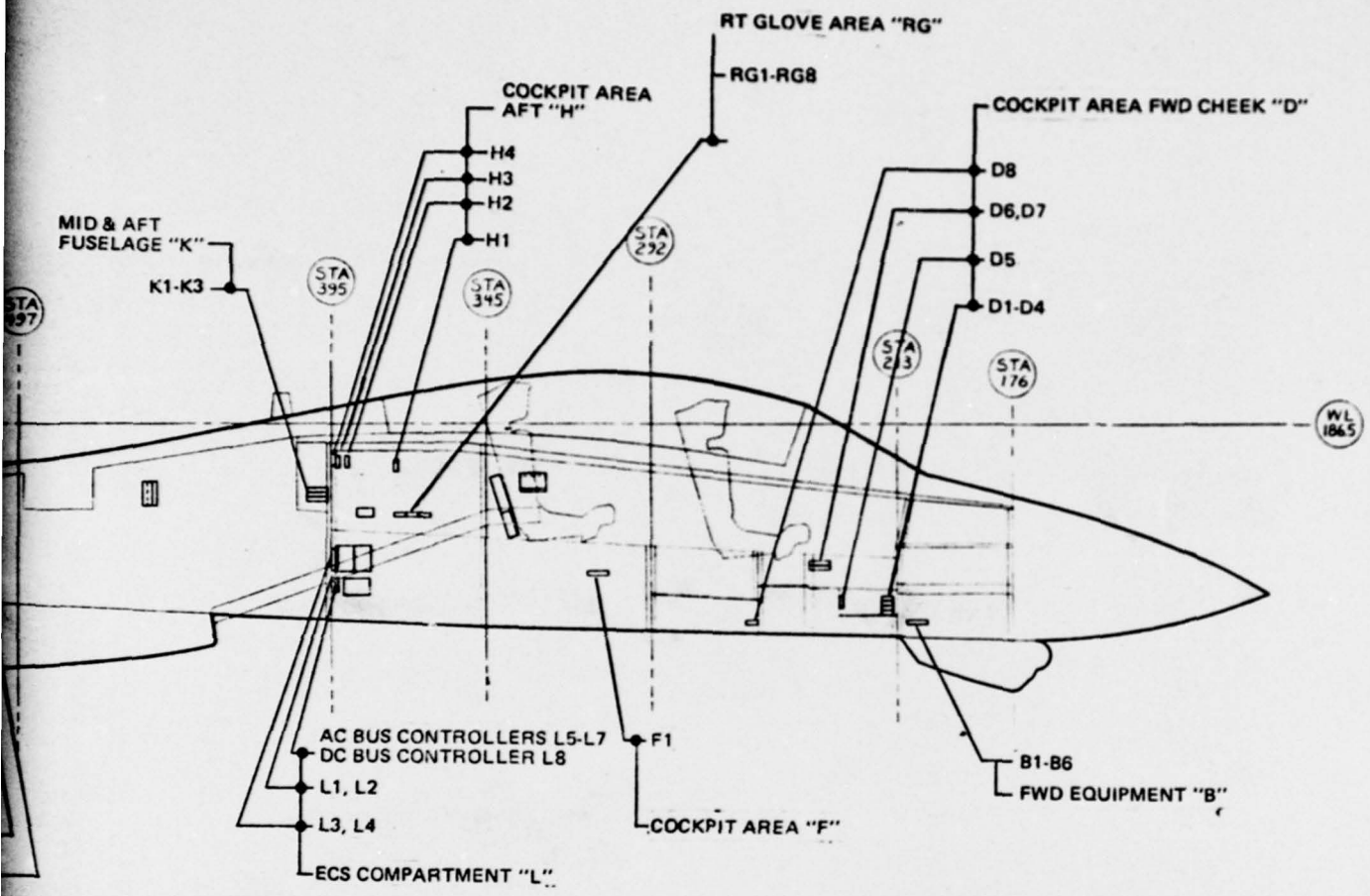
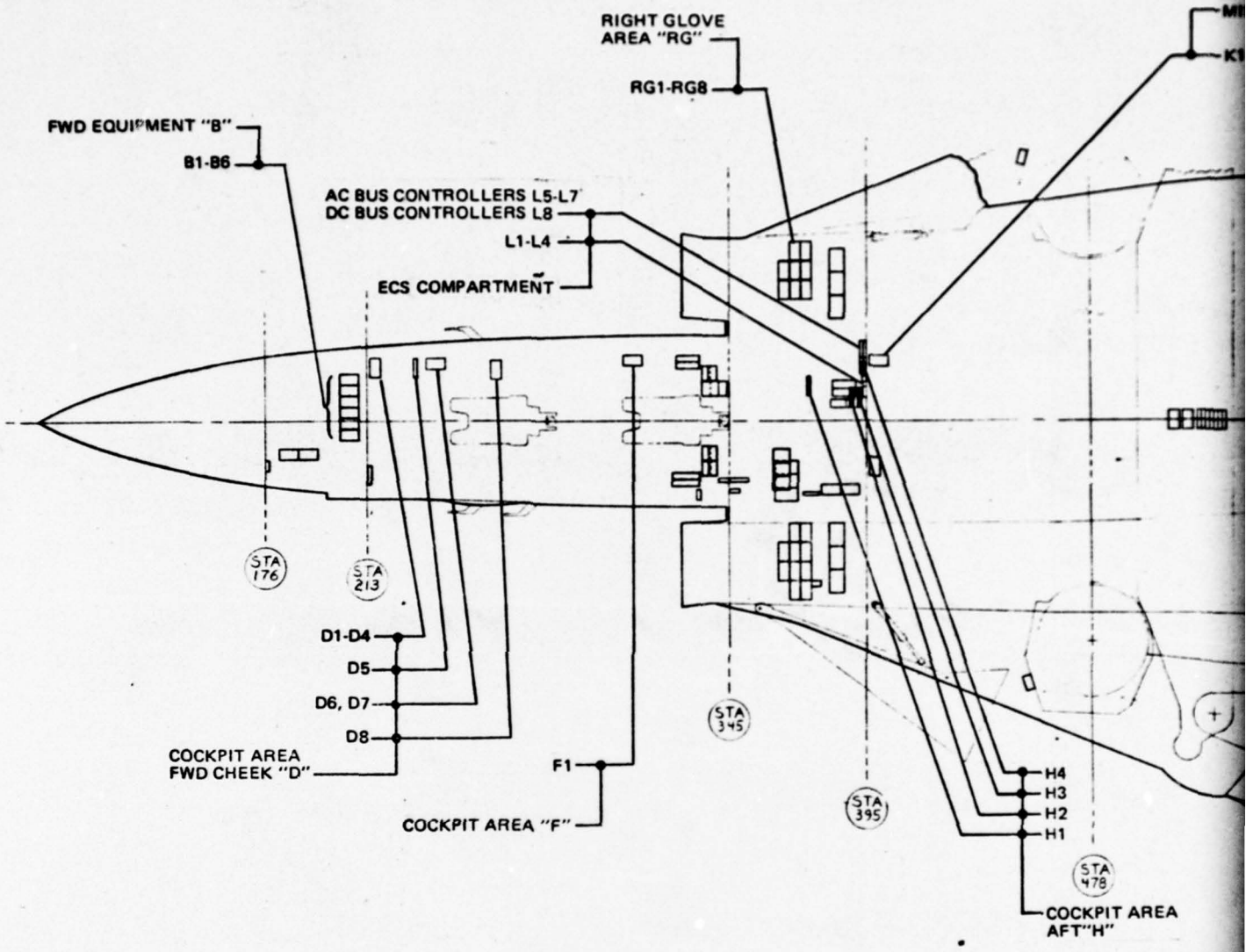


Figure 4-107. Load Power and Bus Controller Module Compartment Location - Starboard Elevation (Sheet 4 of 5)


RIGHT GLOVE
AREA "RG"
RG1-RG8
FWD EQUIPMENT "B"
B1-B6
AC BUS CONTROLLERS L5-L7
DC BUS CONTROLLERS L8
L1-L4
ECS COMPARTMENT
STA 176
STA 213
STA 345
STA 395
STA 478
D1-D4
D5
D6, D7
D8
COCKPIT AREA
FWD CHEEK "D"
F1
COCKPIT AREA "F"
H4
H3
H2
H1
COCKPIT AREA
AFT "H"

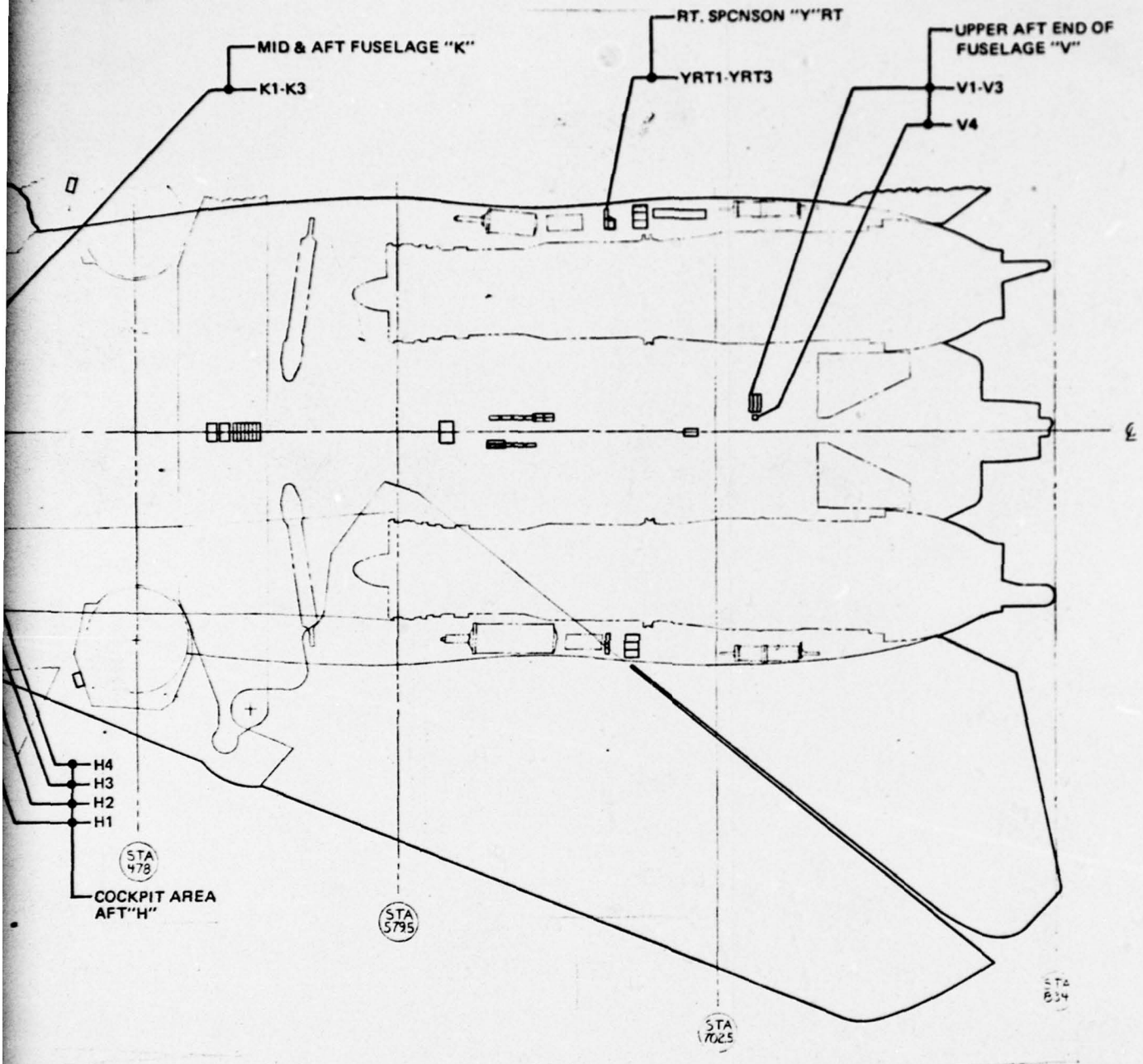


Figure 4-107. Load Power and Bus Controller Module Compartment Installation Layout - Starboard Plan (Sheet 5 of 5)

A survey of the available compartment volumes indicates that the following required OK171 components can be installed in the aircraft:

- 8 GPMS I/O's
- 11 DMUX's
- 7 MUX's
- 2 MUX/DMUX's
- 2 processors
- 1 CCDP

Figure 4-108, the OK171 installation layout, illustrates the location of these components and a typical data bus routing. The locations of the GPMS I/O's, MUX, DMUX, MUX/DMUX were selected so that they are as close as physically possible to their respective interfacing components or loads.

The locations of the processors were selected to provide adequate separation for survivability.

Table 4-47 presents a summary of the actual number of channels used per component. Note that some components have many spare channels due to the fact that their proximity to interfacing components was a criteria rather than actual component quantities.

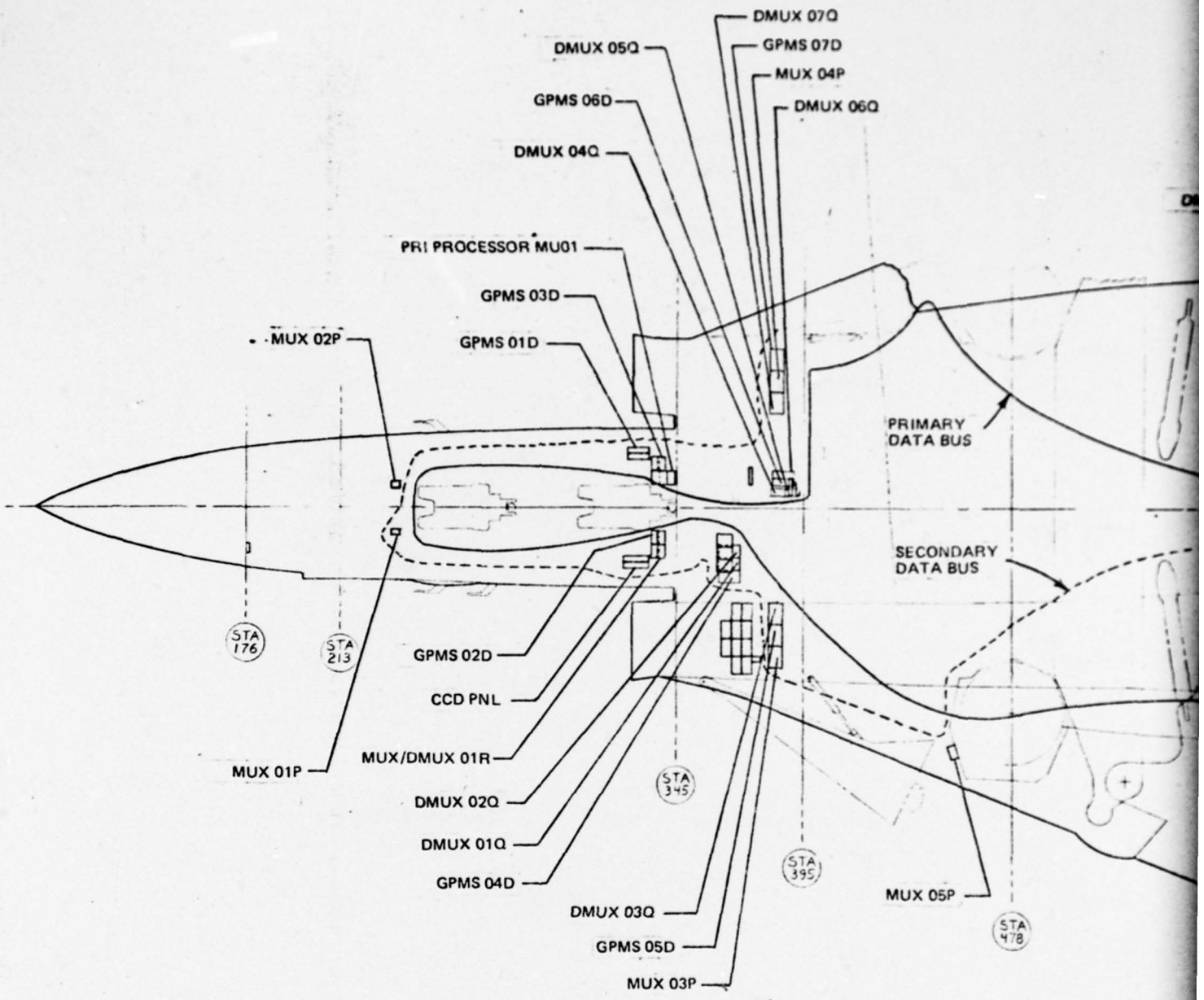
All of the OK171 components can be ambient-cooled to an acceptable case temperature, except the processor MU02 located in the starboard sponson. This processor must be forced cooled and will require 0.3 lb/MIN of air at a supply temperature of 62^{o}F, based on a power dissipation of 73 w packaged into an envelope of 20.6x5.4x3.5 in. The resulting case temperature will be 100^{o}C. The air will be ducted from the environmental control system, Station 380, aft to Station 720. At this point a "T" duct will divert the required flow over the right-hand engine to the processor. The alternate branch of the "T" duct provides air for the existing preamplifier. Light-weight, flexible plastic ducts will be utilized in this area; the new

DOCUMENT PROCESSING CENTER

ITEM	LOCATION	COMPARTMENT	STATION	
GPMS 01D	COCKPIT CIRCUIT BREAKER PNL 35A5	COCKPIT	320	LOW
GPMS 02D	COCKPIT CIRCUIT BREAKER 35A3, 36A1	COCKPIT	320	LOW
GPMS 03D	COCKPIT CIRCUIT BREAKER PNL 36A2	COCKPIT	320	MU C
GPMS 04D	COCKPIT AREA COMPARTMENT - PORT SIDE AFT CHEEK	I	345-395	LOW
GPMS 05D	PORT GLOVE AREA	LG	345-395	SAM
GPMS 06D	ECS COMPARTMENT - STARBOARD SIDE	L	345-395	LOW
GPMS 07D	STARBOARD GLOVE AREA	RG	345-395	SAM
GPMS 08D	STARBOARD SPONSON	Y	640-AFT	MU C
DMUX 01Q	COCKPIT AREA COMPARTMENT - PORT SIDE AFT CHEEK	I	345-395	SSPC
DMUX 02Q	COCKPIT AREA COMPARTMENT - PORT SIDE AFT CHEEK	I	345-395	SSPC
DMUX 03Q	PORT GLOVE AREA	LG	345-395	SSPC
DMUX 04Q	ECS COMPARTMENT STARBOARD SIDE	L	345-395	SSPC
DMUX 05Q	ECS COMPARTMENT STARBOARD SIDE	L	345-395	SSPC
DMUX 06Q	ECS COMPARTMENT STARBOARD SIDE	L	345-395	SSPC
DMUX 07Q	STARBOARD GLOVE AREA		345-395	SSPC
DMUX 08Q	BOTTOM FUSELAGE	P	497-AFT	SSPC
DMUX 09Q	PORT SPONSON	Y	640-AFT	SSPC
DMUX 10Q	STARBOARD SPONSON	Y	640-AFT	SSPC
DMUX 11Q	FLIGHT CONTROL TROUGH	U	579-AFT	SSPC
MUX 01P	COCKPIT CIRCUIT BREAKER PNL 35A6	COCKPIT	230	SAM
MUX 02P	COCKPIT CIRCUIT BREAKER PNL 36A3	COCKPIT	230	SAM
MUX 03P	PORT GLOVE AREA	LG	345-395	SAM
MUX 04P	STARBOARD GLOVE AREA	RG	345-395	SAM
MUX 05P	WHEEL WELL AREA - PORT SIDE	–	460	SAM
MUX 06P	PORT SPONSON	Y	640-AFT	SAM
MUX 07P	STARBOARD SPONSON	Y	640-AFT	SAM
MUX/DMUX 01R	COCKPIT CIRCUIT BREAKER PNL 35A1	COCKPIT	230	CCD
MUX/DMUX 02R	STARBOARD SPONSON	Y	640-AFT	PGS
PRI PROC MU01	COCKPIT CIRCUIT BREAKER PNL 36A4	COCKPIT	320	
SEC PROC MU02	STARBOARD SPONSON	Y	640-AFT	
CCD PNL	COCKPIT CIRCUIT BREAKER PNL 35A2, 35A4	COCKPIT	230	

COMPARTMENT	STATION	FUNCTION & COMMENTS
COCKPIT	320	LOW POWER DRIVERS FOR FLAGS, DISCRETES, ETC.
COCKPIT	320	LOW POWER DRIVERS FOR FLAGS, DISCRETES, ETC.
COCKPIT	320	MU 01 PROCESSOR INTERFACE
I	345-395	LOW POWER DRIVERS FOR FLAGS, DISCRETES, ETC.
LG	345-395	SAMPLE NON-SOSTEL SIGNAL SOURCES
L	345-395	LOW POWER DRIVERS FOR FLAGS, DISCRETES, ETC.
RG	345-395	SAMPLE NON-SOSTEL SIGNAL SOURCES
Y	640-AFT	MU 02 PROCESSOR INTERFACE
I	345-395	SSPC DRIVER
I	345-395	SSPC DRIVERS
LG	345-395	SSPC DRIVER
L	345-395	SSPC DRIVER
L	345-395	SSPC DRIVERS
L	345-395	SSPC DRIVERS
	345-395	SSPC DRIVERS
P	497-AFT	SSPC DRIVERS
Y	640-AFT	SSPC DRIVERS
Y	640-AFT	SSPC DRIVERS
U	579-AFT	SSPC DRIVERS
COCKPIT	230	SAMPLE SOSTEL TRANDUCERS
COCKPIT	230	SAMPLE SOSTEL TRANDUCERS
LG	345-395	SAMPLE SOSTEL TRANDUCERS
RG	345-395	SAMPLE SOSTEL TRANDUCERS
–	460	SAMPLE SOSTEL TRANDUCERS
Y	640-AFT	SAMPLE SOSTEL TRANDUCERS
Y	640-AFT	SAMPLE SOSTEL TRANDUCERS
COCKPIT	230	CCDP INTERFACE
Y	640-AFT	PGS INTERFACE
COCKPIT	320	
Y	640-AFT	
COCKPIT	230	

Figure 4-108. Control Group OK171 Installation Layout (Sheet 1 of 4)


DMUX 07Q
DMUX 05Q
GPMS 07D
MUX 04P
GPMS 06D
DMUX 06Q
DMUX 04Q
PRI PROCESSOR MU01
GPMS 03D
MUX 02P
GPMS 01D
PRIMARY DATA BUS
SECONDARY DATA BUS
STA 176
STA 213
GPMS 02D
CCD PNL
MUX/DMUX 01R
MUX 01P
DMUX 02Q
DMUX 01Q
GPMS 04D
STA 345
STA 395
DMUX 03Q
GPMS 05D
MUX 03P
MUX 05P
STA 478

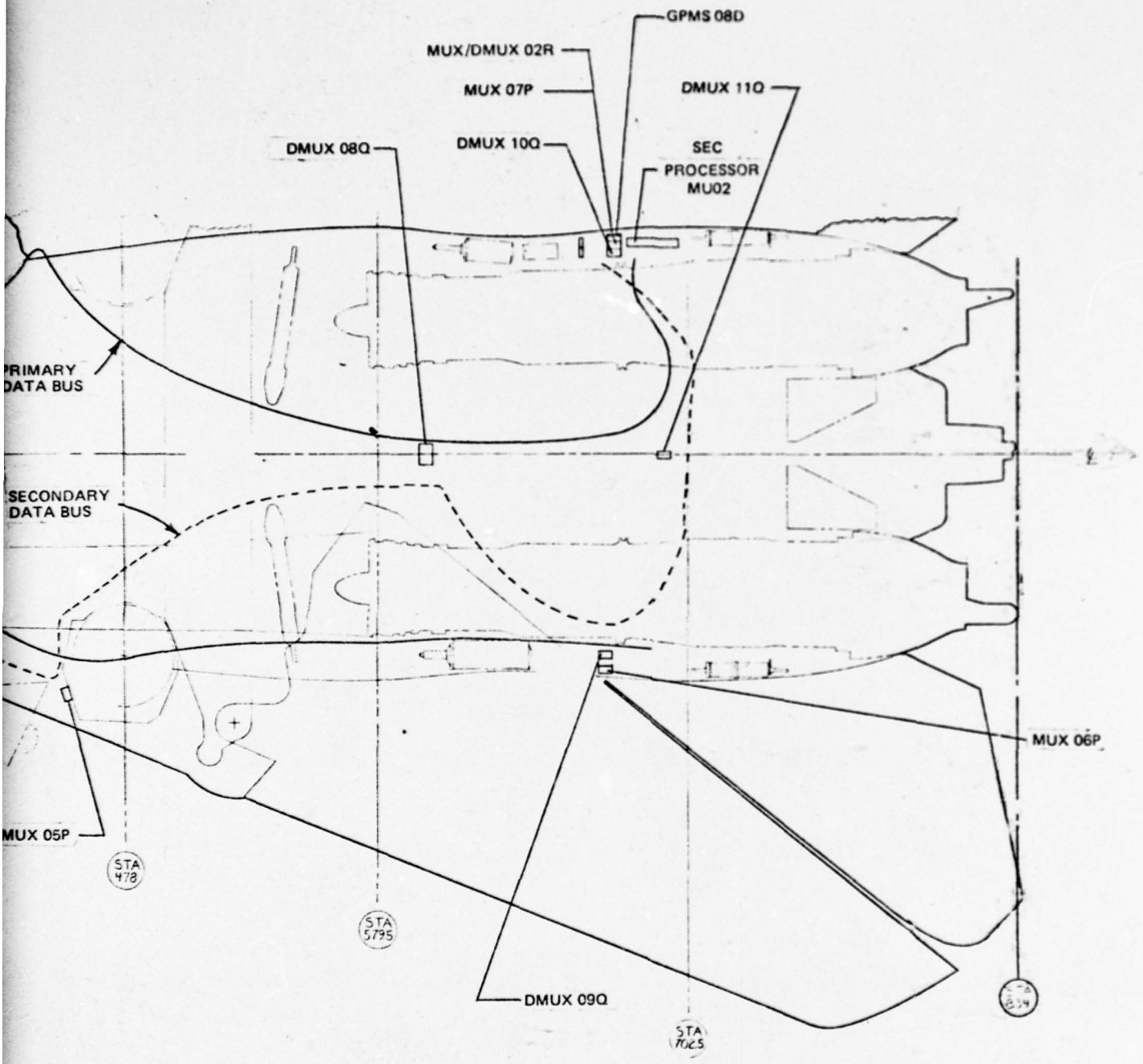
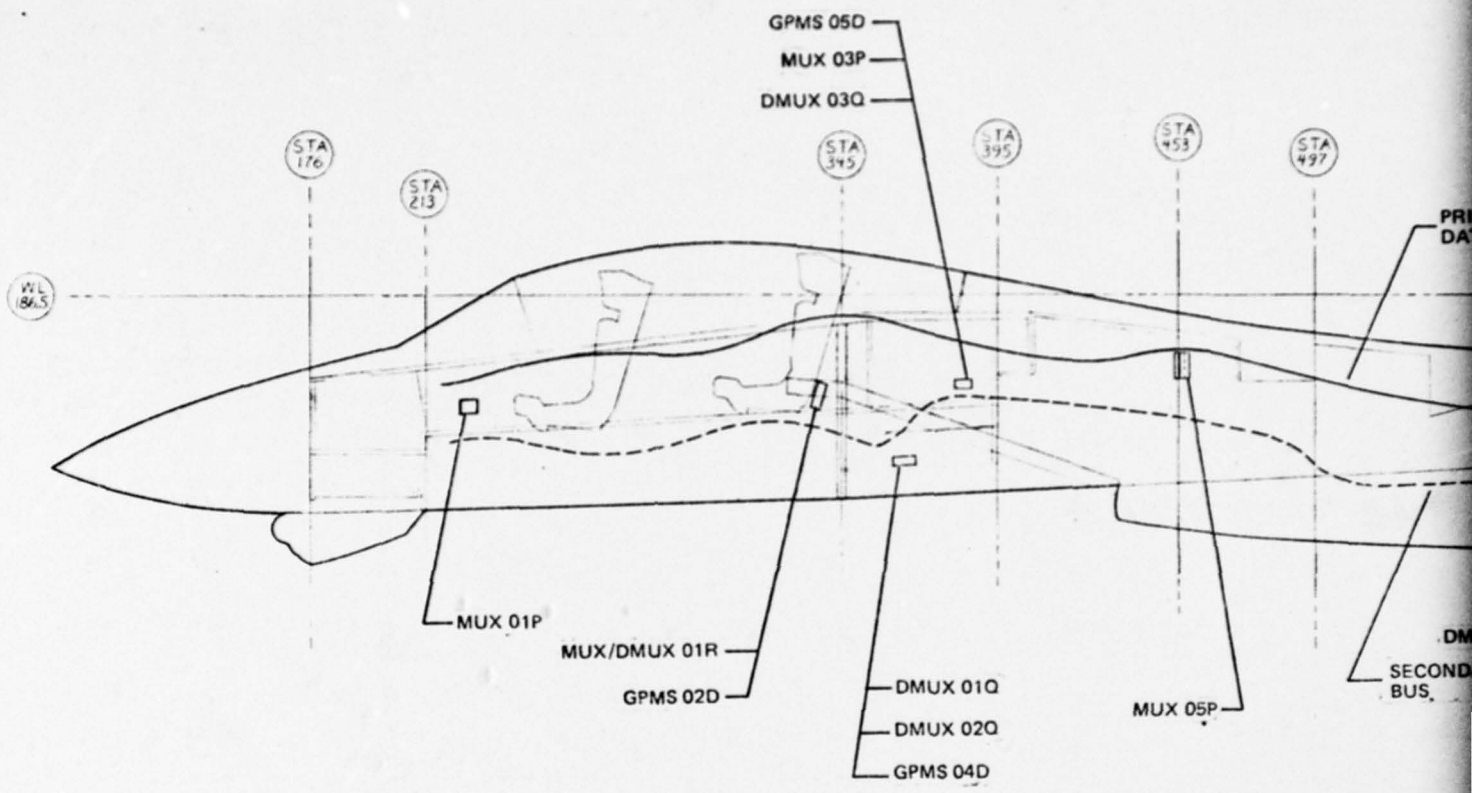


Figure 4-108. Control Group OK171
Installation Layout - Plan Port
(Sheet 2 of 4)


GPMS 05D
MUX 03P
DMUX 03Q
STA 176
STA 213
STA 345
STA 395
STA 453
STA 497
WL 186.5
MUX 01P
MUX/DMUX 01R
GPMS 02D
DMUX 01Q
DMUX 02Q
GPMS 04D
MUX 05P
SECOND
BUS.

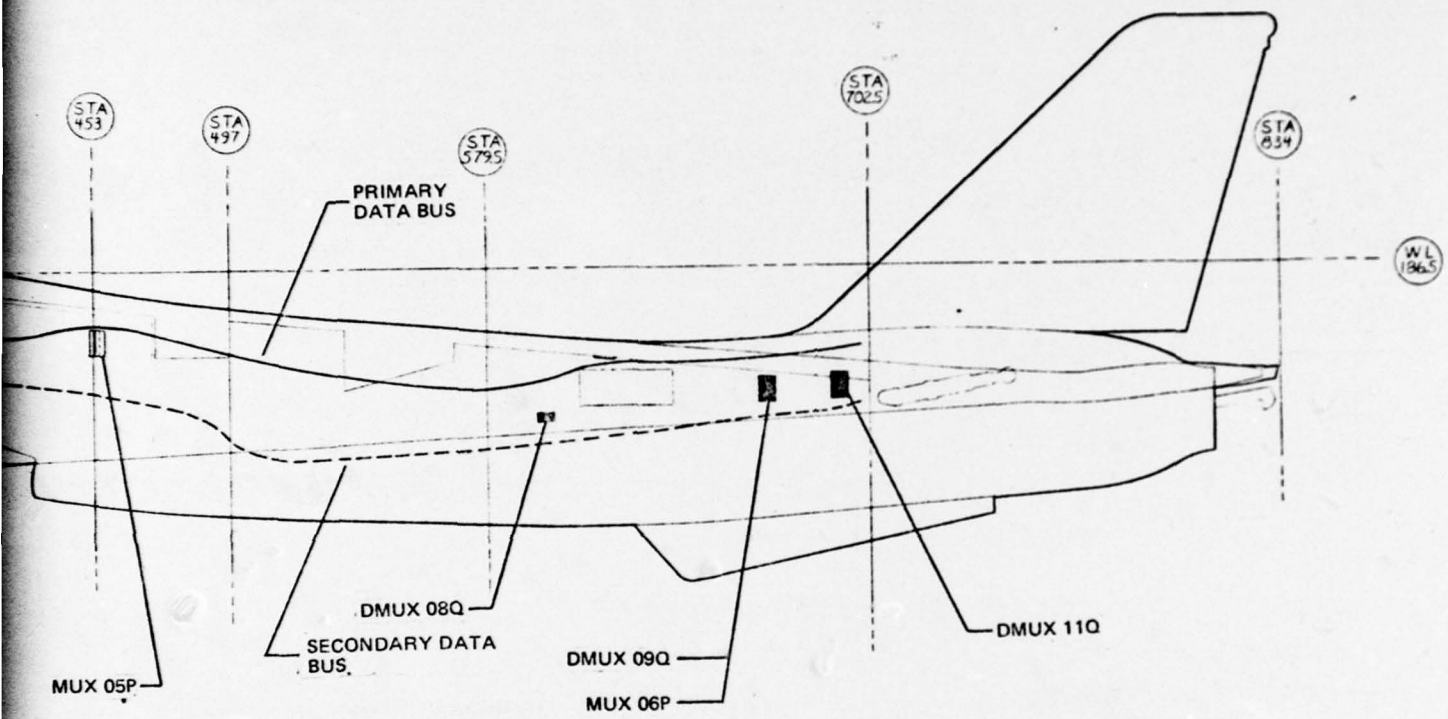
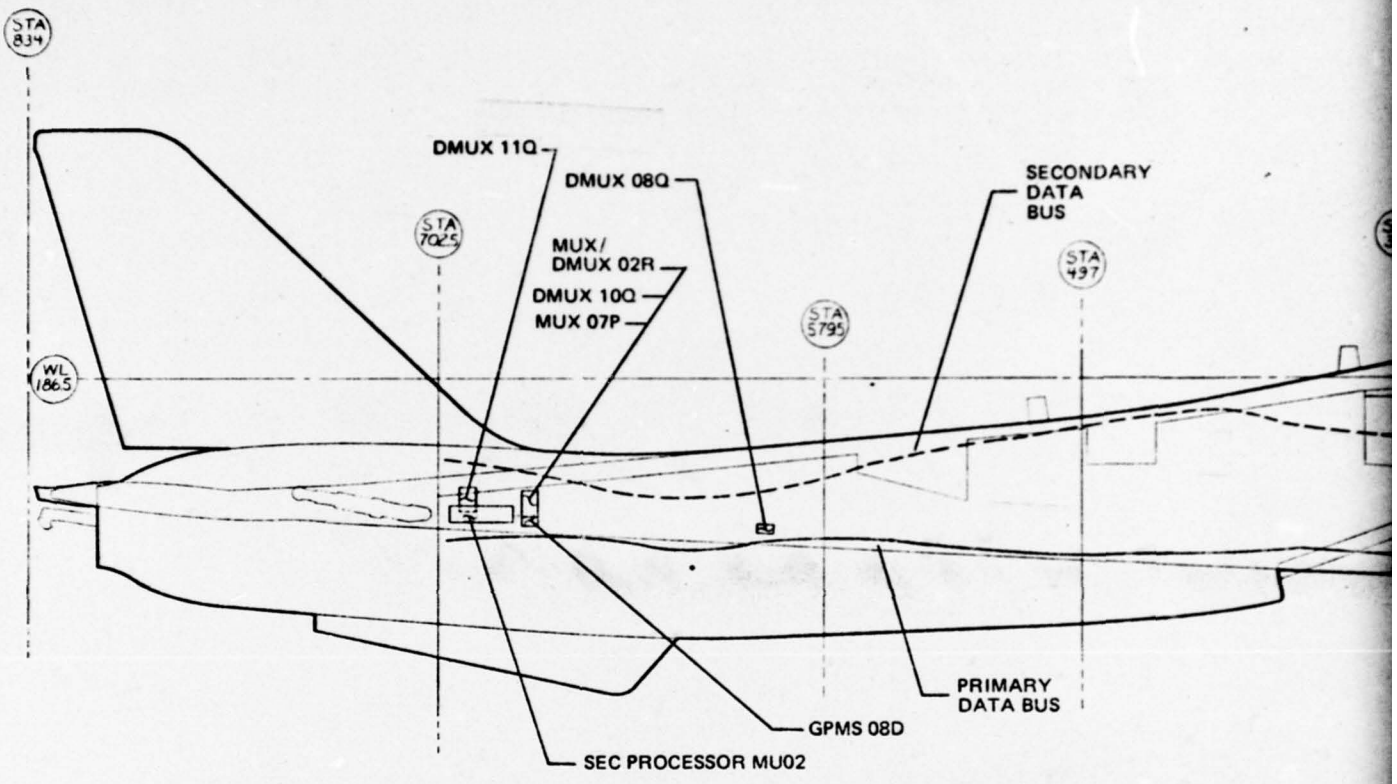


Figure 4-108. Control Group OK171 Installation Layout - Port Elevation (Sheet 3 of 4)


STA 834
DMUX 11Q
DMUX 08Q
SECONDARY DATA BUS
STA 702.5
MUX/ DMUX 02R
DMUX 10Q
MUX 07P
STA 497
STA 579.5
WL 186.5
PRIMARY DATA BUS
GPMS 08D
SEC PROCESSOR MU02

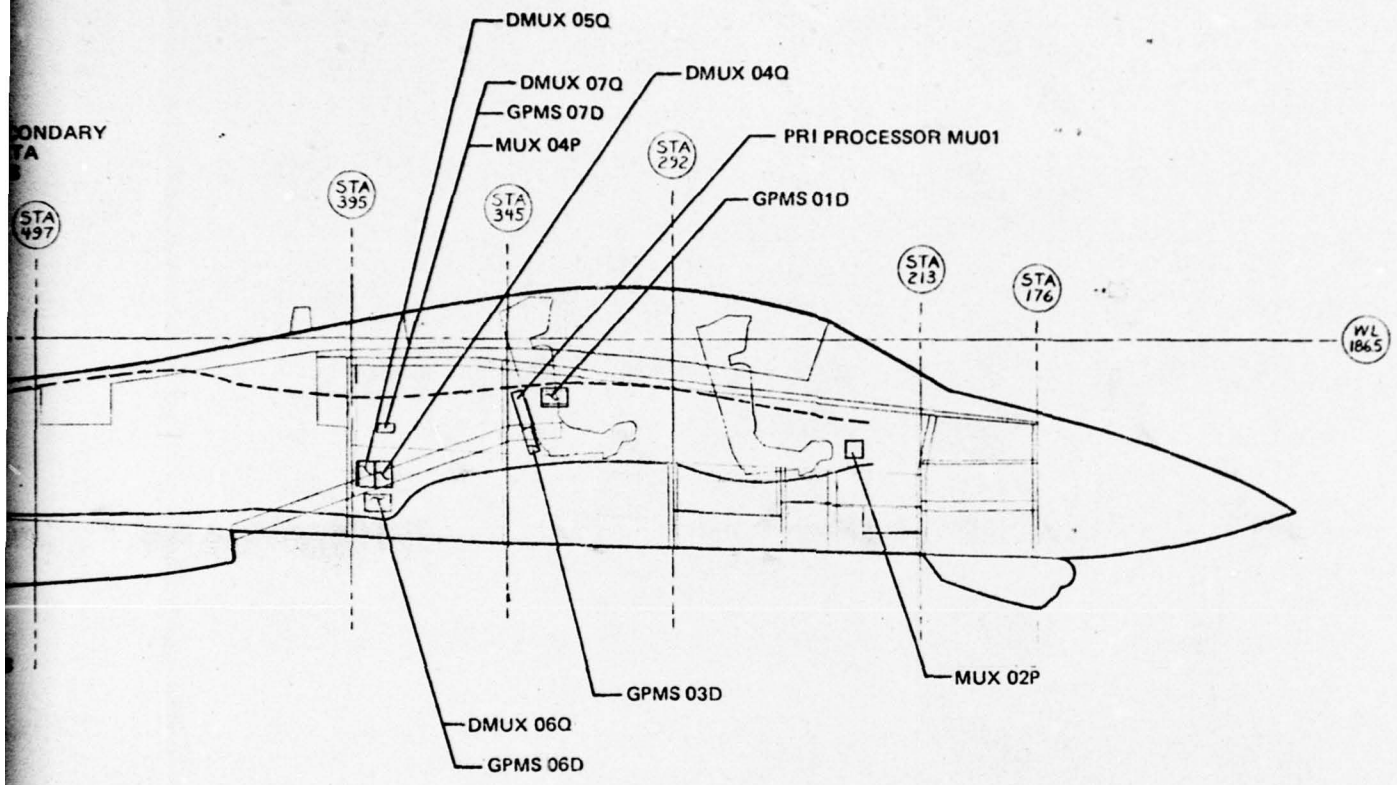


Figure 4-108. Control Group OK171 Installation Layout - Starboard Elevation (Sheet 4 of 4)

TABLE 4-47. OK171 COMPONENT CHANNEL USAGE SUMMARY

Component	No. of Channels used	Remarks
GPMS 01D	51	Flag, lamp, etc, drivers (see Table 4-45)
02D	56	Flag, lamp, etc, drivers (See Table 4-45)
03D	-	Interface witch cockpit processor MU01
04D	37	Driver of discretes in port side compartments A, C, E, G, I, J
05D	48	Non-SOSTEL conditioned input signals
06D	42	Driver of discretes in starboard side Compartments B, D, F, H, K and Y.
07D	46	Non-SOSTEL conditioned input signals
08D	-	Interface with right sponson processor MU02
DEMUX 01Q	63	Power controller interface in port side
02Q	17	Compartments A, C, E, G, I, J
03Q	50	Power controller interface in left glove area
04Q	63	Power controller interface in starboard side
05Q	63	Compartments B, D, F, H, L, K
06Q	5	Power controller interface in compartment K
07Q	38	Power controller interface in right glove area
08Q	57	Power controller interface in Compartment P
09Q	12	Power controller interface in Compartment YLF
10Q	10	Power controller interface in Compartment YRT
11Q	37	Power controller interface in Compartments U and V
MUX 01P	60	SOSTEL Transducers
02P	61	SOSTEL Transducers
03P	37	SOSTEL Transducers
04P	38	SOSTEL Transducers
05P	27	SOSTEL Transducers
06P	41	SOSTEL Transducers
07P	41	SOSTEL Transducers
MUX/DEMUX 01R	-	Interface with CCDP
MUX/DEMUX 02R	-	Interface with PGS

ducts will be slightly enlarged over the current ducts to accommodate the higher total flow requirements. Fig. 4-109 illustrates the processor cooling line runs.

A summary of all the case temperatures follows:

Component	Temperature, ^{o}C
Processor MU01	95*
Processor MU02	100
DMUX01Q to 11Q	104
MUX01P, 02P	59*
MUX03P, to 07P	104
GPMS01D to 03D	59*
GPMS04D to 08D	104
MUX/DMUX 01R	59*
MUX/DMUX 02R	104
CCDP	59

- - - - - - - - - - -

*The case temperatures of these components are considerably less than their respective counterparts due to the fact that they are located in the cockpit ambient of 27^{o}C.

4.2.11 WEIGHT SUMMARY

This study indicates that a weight penalty of 181.51 pounds would be incurred to provide a SOSTEL system for the F-14A aircraft.

Table 4-48 and 4-49 presents a weight summary of the items removed and added, respectively. The tabulation (parts I and II) following provides a detailed breakdown of this weight summary (refer to general notes at the end of the part II tabulation).

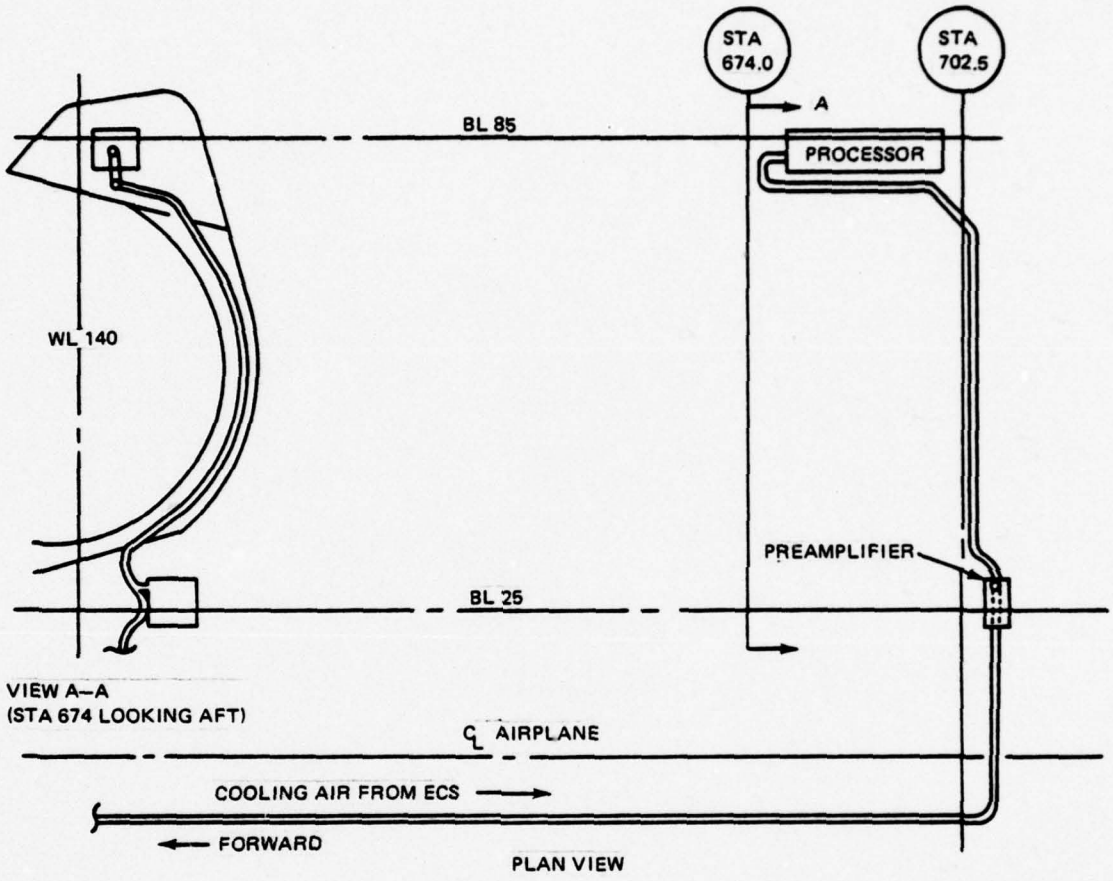


Figure 4-109. Processor Cooling

Table 4-48 Weight Removed

Item	Weight, lb
Circuit Breaker Panels	51.8
Components & Boxes	49.51
Wire - Bus	8.55
Wire - Load	41.08
Connectors	14.43
Total Weight	165.37

Table 4-49 Weight Added

Item	Weight, lb
Power Controllers (PC)	79.7
*PC Module Assemblies	52.3
Bus Controllers	8.0
Load Wire	9.31
Bus Wire	5.12
Wiring DMUX, MUX, GPMS DT to signals or loads	14.75
SOSTEL Bus	2.61
Processors (2)	36.0
**MUX's (7)	23.1
**DMUX's (11)	55.0
*GPMS DT (8)	40.0
MUX/DMUX (2)	15.0
*CCD Panel	6.0
Total Weight	346.88

*Required for prototype stand alone SOSTEL system, may not be required for GPMS/SOSTEL production aircraft

**Can be reduced by use of MUX/DEMUX terminals.

I. Weight Removed

- Circuit Breaker Panels

Panel	Designation	Total Weight, lb
Right A-C Main	35 A1	7.1
Left A-C Ess. No. 2	35 A2	4.0
A-C Ess. No. 1	35 A3	2.3
A-C Ess. No. 2	35 A4	3.5
Left A-C Main	35 A5	10.4
Pilots A-C Ess. No. 2	35 A6	2.9
D-C Ess. No. 1	36 A1	4.4
D-C Ess. No. 2	36 A2	5.7
Pilots D-C Ess.	36 A3	2.8
D-C Main	36 A4	8.7
		51.8

- Components and Boxes

Item	Designation	Total Weight, lb
Right Glove Relay Box	772A1	19.6
Left Glove Relay Box	773A1	22.5
Aft Cockpit Relay Box	793A1	1.8
Fwd. Switching Ass'y	781A1	1.5
A-C Transfer Relay	A51A9121	0.75
D-C Transfer Relay	A51A9122-1	0.36
A-C Flasher	600519	1.5
Rain Repellant Timer	40 M2	0.40
Hyd. Back-up Module Ass'y	787A1	1.10
		49.51

- Wire - Bus Cable

Cable	Total Weight, lb
Left Contactor to CB Pnl 35A5	1.9
Right Contactor to CB Pnl 35A1	1.6
Transfer Relay to CB Pnl 35A2 and 35A4	0.8
Transfer Relay to left contactor	0.3
Transfer Relay to CB Pnl 35A3	1.6
CB Pnl 35A5 to L. Main TR	0.5
CB Pnl 35A1 to R. Main TR	0.44
D-C Power Contactor to CB Pnl 36A4	0.47
Transfer Relay to CB Pnl 36A1	0.47
Transfer Relay to CB Pnl 36A2	0.47
	8.55

Wire CB Panels to Loads

	Total Weight, lb
CB to loads (600) (see note 1)	41.08

Connectors (see note 2)

Item	Quantity	Weight per unit, lb	Total Weight, lb
Pins	3069	0.00066	2.03
Socket	3069/61 = 50	0.00107	.05
Plug	3069/61 = 50	0.119	5.95
Receptable	3069/61 = 50	0.128	6.40
			14.43

II. Weight Added

- Power Controllers

Type	Weight, oz	Quantity	Total Weight, oz
28 vdc, 2 amp	2.5	116	290.0
28 vdc, 5 amp	2.5	39	97.5
28 vdc, 10 amp	3.0	23	69.0
115 v, 2 amp	3.0	176	528.0
115 v, 5 amp	3.0	12	36.0
115 v, 10 amp (est)	4.0	47	188.0
115 v, 50 amp (est)	3.4	2	68.0
			1276.5 oz
			(79.7 lb)

- Power Controller - Module Ass'y per Drawing Fig. 4-102 and 4-103

Weight of aluminum plate = 4 x 7 x 0.62 in. (0.1 lb/in.^{3}) = 0.174 lb

Weight of cooling fins = 26 (7x0.25x0.03 in.) x (0.1 lb/in.^{3}) = 0.135 lb

Termination (Bracket and connector) 0.250 lb

0.559 lb

Total Weight = Total No. of modules x 0.559

= 94 x 0.559 = 52.3 lb

Bus Controllers

Type	Weight, lb	Quantity	Total Weight, lb
115 v, 400 Hz, 100 amp	1 (est)	6	6.0
28 vdc, 75 amp	1 (est)	2	2.0
			8.0

- Load Wire

2 amp Loads

Total 2 amp loads = 116 (dc) + 176 (ac) = 292

Wire Size required - AWG 24 (2.1 lb/1000 ft)

Average length of SSPC module to loads = 6 ft

Wire Weight = 292 x 6 (2.1×10^{-3}) = 3.67 lb

5 amp Loads

Total 5 amp loads = 39 (dc) + 12 (ac) = 51

Wire Size required - AWG 22 (3.0 lb/1000 ft)

Average length of SSPC modules to loads = 6 ft

Wire Weight = 51 x 6 (3.0×10^{-3}) = 0.92 lb

10 amp Loads

Total 10 amp loads = 23 (dc) + 47 (ac) = 70

Wire Size required - AWG 18 (6.8 lb/1000 ft)

Average length of SSPC modules to loads = 6 ft

Wire Weight = 70 x 6 (6.8×10^{-3}) = 2.86 lb

30 amp Loads

Total 30 amp loads = 2 (ac) 3Ø

Wire Size required - AWG 10 (31.3 lb/1000 ft)

Average length of SSPC modules to loads = 10 ft

Wire Weight = 6 x 10 (31×10^{-3}) = 1.86 lb

Total Load Wire Weight = 3.67 + .92 + 2.86 + 1.86 = 9.31 lb

Bus Wire

AC Power Contactors to six a-c Bus controllers

Wire size required AWG 04 (141 lb/1000 ft)

Average Length = 5 ft

Bus Weight = 6 x 5 (141×10^{-3}) = 4.23 lb

D-C Power Contactors to two d-c Bus Controllers Wire size required

06 AWG (88.6 lb/1000 ft)

Average length - 5 ft

Bus Weight = 2 x 5 (88.6×10^{-3}) = 0.89 lb

Total Bus Weight = 4.23 + .89 = 5.12 lb

Wiring DMUX's to SSPC

Total DMUX's - 11 (63 outputs/terminal)

Signal Wire required - AWG 26 (1.5 lb/1000 ft)

Average wire length - 6 ft

Wire Weight = 11 x 63 x 6 (1.5×10^{-3}) = 6.25 lb

Wiring MUX's to Transducers

Total MUX's = 7 (63 inputs/terminal)

Signal Wire required = AWG 26 (1.5 lb/1000 ft)

Average wire length = 6 ft

Wire Weight = 7 x 63 x 6 (1.5×10^{-3}) = 4.0 lb

Wiring GPMS DT to Signals

Total DPMS DT = 8 (63 channels/terminal)

Signal Wire required = AWG 26 (1.5 lb/1000 ft)

Average wire length = 6 ft

Wire Weight = 8 x 63 x 6 (1.5×10^{-3}) = 4.5 lb

Total Terminal Wire weight = 6.25 + 4.0 + 4.5 = 14.75 lb

SOSTEL Buses (two required)

Type = Twisted shielded pair (RG 103 A/U or equivalent)

Length = 45 ft per pair

Weight = 2.9 lb/100 ft

Wire Weight = 2 x 45 (2.9×10^{-2}) = 2.61 lb

SOSTEL Components (see Note 3)

Item	Quantity	Weight/Unit, lb	Total Weight, lb
Processor	2	18	36
MUX	7	3.3	23.1
DEMUX	11	5	55
GPMS DT	8	5	40
MUX/DEMUX	2	7.5	15
CCDP	1	6	6
			175.1

Notes:

1. Typical calculation of load wire weight removal.

   Load - Flight Control Back-up Module Motor at Sta 720.

   Circuit Breakers - CB 30, CB 32, CB 34 on panel 35A1, at Sta 290.

   Wire Size - 10 AWG (31.3 lb/1000 ft)

   Length Wire - (720 - 290 in.) x 1.5 = 645 in.

   The 1.5 factor is an estimated correction factor, since the station-to-station wire routing is not a straight line point to point run.

   Wire Weight - $\frac{645}{12} \times (31.1 \times 10^{-3}) \times 3 = 5.05$ lb

2. Total number of pins removed 3069

   Average shell size 22 (61 pins)

   Average pin size 20.

3. The weights listed are projected from present units on the assumptions of a reduction in circuit complexity.

4.3 RELIABILITY

The reliability effort on the AAES program concentrated on three major areas

- Power Generation
- SOSTEL Control Group Equipments
- Solid State Power Controllers.

In each of the foregoing areas, MTBF data was collected from potential vendors, the F-14 program, 3M data; where possible, Grumman in-house predictions were performed using MIL HBK 217B failure rates. The results of these analyses, although preliminary in nature, indicate the need for further in-depth study and illustrate the tremendous impact that basic design decisions (such as need for internal redundancy, SSPC cooling requirements, etc) have upon system cost and reliability.

4.3.1 RESULTS AND CONCLUSIONS

- Power Generation
  - The reliability of all power generation configurations analyzed is acceptable
  - Systems without essential buses have the highest reliability
  - Systems with a separate transformer rectifier will have a higher reliability than those with an integral transformer rectifier.
  - PGS mission MTBF goal of 1500 hr is realistic and achievable
- SOSTEL Group III
  - From a cost/benefit and mission reliability viewpoint, internal redundancy cannot be justified for both the MUX and DEMUX
  - Total internal redundancy in the MUX and DEMUX will essentially double the cost without significantly improving aircraft reliability
  - A single thread (no redundancy) SOSTEL system (see Fig. 4-110) consisting of a representative group of equipment (processor, CCDP, 1 MUX/DEMUX, 10 MUX's and 7 DEMUX's) have a mission MTBF of 164 hr. It was conservatively assumed that all interface and input/output SOSTEL functions were required for mission success

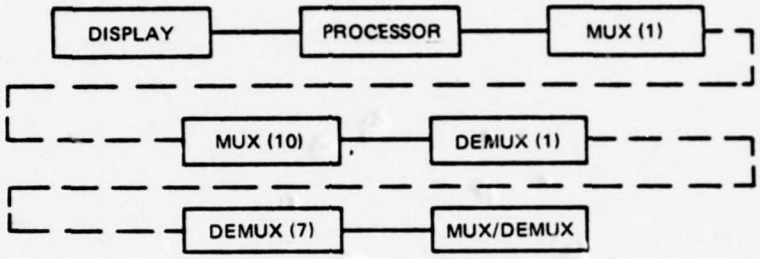


Figure 4-110. Single Thread (No Redundancy) SOSTEL Control Group

- The SOSTEL mission MTBF goal of 4000 hr may be unrealistic and unachievable without excessive cost, weight, and volume penalties in a full up F-14 with 100% SOSTEL capability.
- To improve SOSTEL Group III mission reliability, the following recommendations are suggested:
  - o Reduce the overall parts count and increase reliability by increased usage of MUX/DEMUX components as opposed to separate units
  - o Investigate the reliability impact of the use of JAN TX, M38510 Class B microelectronics and ER resistors and capacitors in all equipment
  - o More detailed reliability models should be generated to better evaluate the impact of failure on the probability of mission success. Present models assume a full capacity is required for mission success
  - o Evaluate the impact of adding redundancy for the CCDP and improving the reliability of the basic displays
  - o Continue to research state of the art improvements that would result in increased system reliability
  - o The calculations of black box MTBF used Method 3 of MIL HBK 217B, which is suitable during preliminary design phases. The more detailed procedures of Section 2, which are applicable as design details (such as individual part temperatures, stresses, etc) are identified and will result in a more favorable reliability assessment.

- Solid State Power Controllers (SSPC)
  - Active cooling for SSPC's should be investigated since the MTBF of the individual controllers varies with temperature as follows:

    22,800 hr at 100°C case

    48,400 hr at 71°C case

    91,000 hr at 50°C case

    217,000 hr at 25°C case

    Since there will be approximately 400 such power controllers, SSPC temperatures will significantly impact aircraft reliability and availability.

4.3.2 DISCUSSION

Reliability estimates were obtained from potential suppliers for the major AAES equipments as illustrated in Table 4-50. As the design effort progressed these estimates were updated and refined to reflect the increasing depth of analysis. The final data used in the analyses of this report are noted by an (1) in the MTBF column.

4.3.2.1 Power Generation Subsystem

The reliability effort in the power generation area concentrated in preparing math models (Fig. 4-111 through 4-118) of the eight candidate power generation configurations described in Subsection 4.1.2.2, and computing their associated reliabilities. The results of the preliminary reliability trades are summarized in Table 4-51, and indicate that the subsystem without essential buses (configurations II and IV) are the most reliable. Although not apparent from Table 4-51, it is expected that systems with separate transformer rectifiers (TR) will have higher reliability than systems with integral TR's. For instance, examination of configurations IIA and IIB reveals reliabilities of 0.999996 and 0.999997 for the integral and separate TR systems respectively. However, the integral TR calculation is based on Bendix data with an MTBF of 2×10^6 hours for a TR internal to the generator. This is considered to be unreaslistically high and a more reasonable MTBF estimate should significantly reduce the reliability of the integral configuration with respect to a separate TR configuration. This could also be concluded qualitatively when one argues that a separate TR provides greater system flexibility since a generator failures does not result in a TR failure as is the case with an integral TR. Note that all the configurations analyzed are acceptable and are capable of achieving the 1500-hour mission MTBF requirement. In the preliminary analysis a conservative five-hour mission time was used for the F-14 instead of a more realistic three-hour mission. The calculations that follow reflect a three-hour mission time.

Since the preliminary analysis was performed the following changes have occured:

TABLE 4-50. MTBF ESTIMATES FOR MAJOR AAES EQUIPMENT (SHEET 1 OF 4)

Equipment	MTBF, hours	Source	Comments
Multiplexer (MUX)	6500	SCI Systems	
	6550	Grumman	Hi reliability parts(2)
	4550(1)	Grumman	Standard Military parts(2)
DeMultiplexer (DEMUX)	5500	SCI Systems	
	4800	Grumman	Hi Reliability parts(2)
	3650(1)	Grumman	Standard Mil parts(2)
MUX/DEMUX	4000(1)	SCI Systems	
Processor	6000(1)	SCI Systems	
Crew Control & Display (CC&D)	6000	SCI Systems	SOSTEL Spec. CC&D
	635(1)	Grumman	Standard Mil parts, 6 x 12 alphanumeric display
AC SSPC 2, 5, 10 amp	300,000	Telephonics	
DC SSPC 2, 5, 10 amp	300,000	Telephonics	
	91,000(1)	Grumman	Based on RCA design and MIL HBK 217B at 50°C case temperature.

NOTES:
(1) Values used in this analysis
(2) Microprocessor configured unit

TABLE 4-50. MTBF ESTIMATES FOR MAJOR AAES EQUIPMENT (SHEET 2 OF 4)

Equipment	MTBF, Hours	Source	Comments
AC SSPC	84,400	Westinghouse	2 amp
DC	75,900	Westinghouse	5 amp
	60,700	Westinghouse	10 amp
SSPC	67,400	Westinghouse	2 amp
AC	58,200	Westinghouse	5 amp
	48,400	Westinghouse	10 amp
		PGS	
Power Contactor	28,986[1]	F-14 3M 1/75-6/75	
Transformer Rectifier	6,440[1]	F-14 3M 1/75-6/75	
Transfer Relays	222,222[1]	F-14 3M 1/75-6/75	
VSCF Generator (75 kva)	17,300	Westinghouse	Without gear box
VSCF Convert. & Control	8,000	Westinghouse	
HVDC Generator (75 kw)	14,500	Bendix	Without gear box
	9,200	Bendix	With gear box

TABLE 4-50. MTBF ESTIMATES FOR MAJOR AAES EQUIPMENT

Equipment	MTBF, Hours	Source	Comments
HVDC Control	12,600	Bendix	
HVDC Inverter (40 kva)	11,473	Bendix	
VSCF Gen Sys DC Link 75 kva	7,521	Bendix	Without gear box
VSCF Gen Sys	5,780	Bendix	With gear box - all equipment ambient 25°C
VSCF Gen Sys DC Link 75 kva	3100(1)	Grumman	GAC estimate of Bendix equipment at 70°C ambient
HVDC Gen	12,330	Sundstrand	without gear box
	8,260	Sundstrand	with gear box
HVDC Gen Control Unit	24,000	Sundstrand	
HVDC Gen	1,672	G.E.	
HVDC Gen Control Unit	18,812	G.E.	

TABLE 4-50. MTBF ESTIMATES FOR MAJOR AAES EQUIPMENT (SHEET 4 OF 4)

Equipment	MTBF, Hours	Source	Comments
HVDC Gen	15,800	Westinghouse	without gear box
	9,700	Westinghouse	with gear box
HVDC Gen Control Unit	23,000	Westinghouse	
VSCF Generator	1,060	G.E.	
VSCF Convert/ Control	1,430	G.E.	100% Load
	1,900	G.E.	50% Load

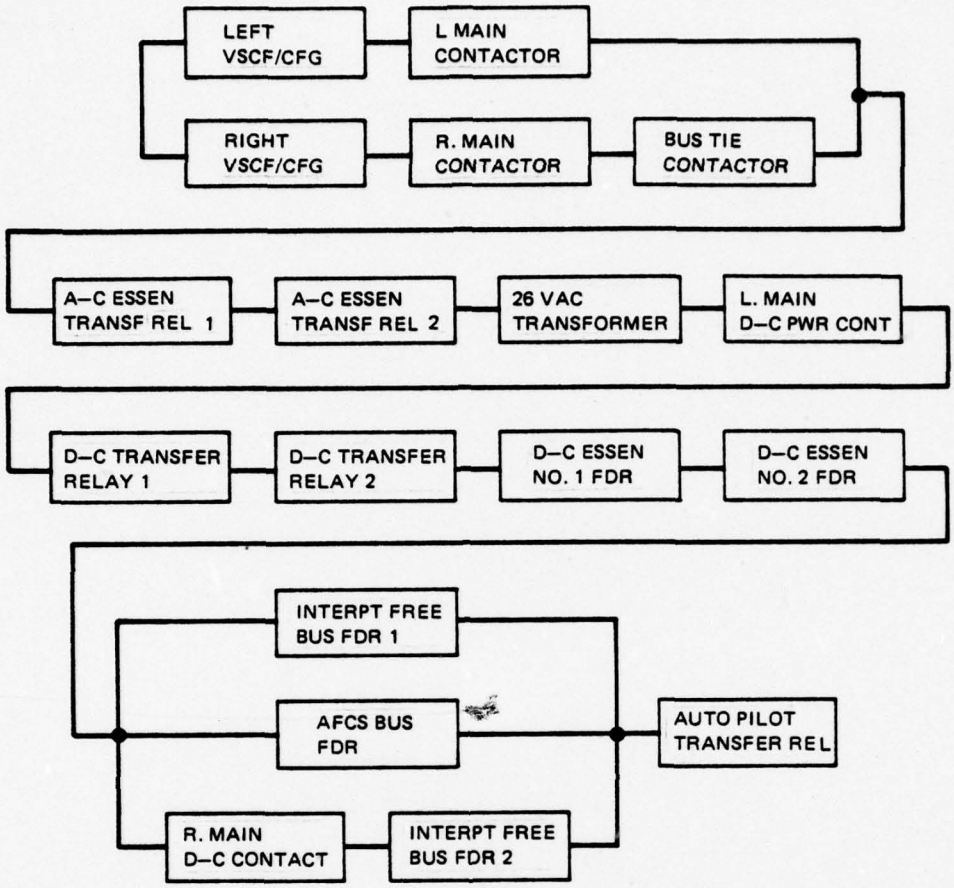


Figure 4-111. Reliability Model - AAES Power Generation Configuration IA

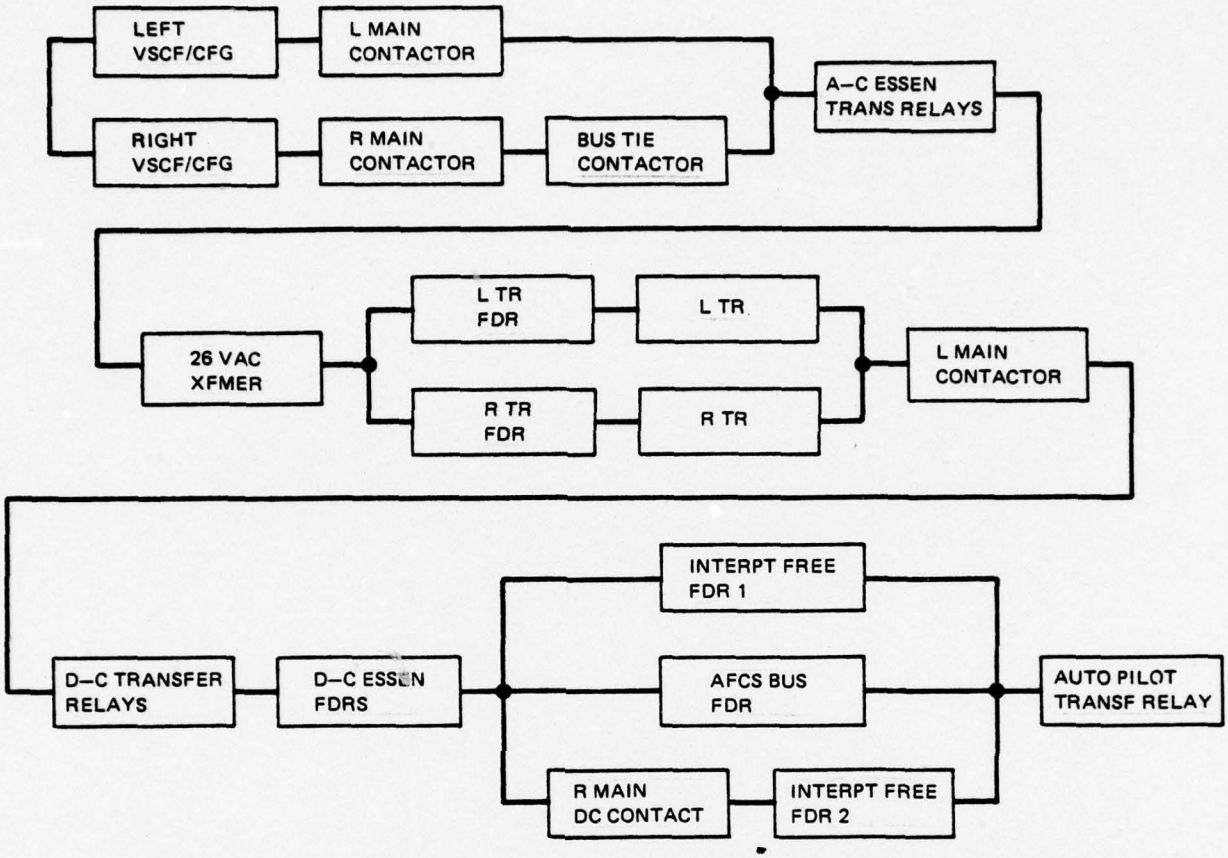


Figure 4-112. Reliability Model - AAES Power Generation Configuration IB

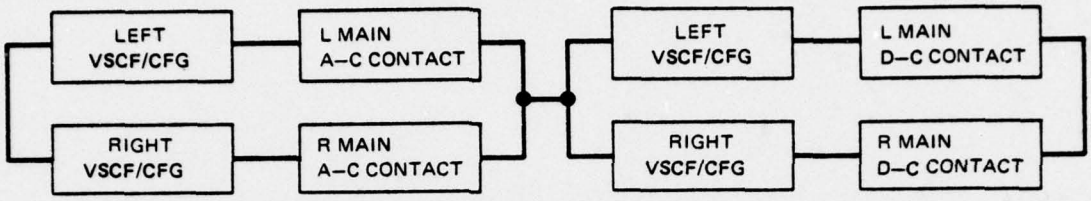


Figure 4-113. Reliability Model - AAES Power Generation Configuration IIA

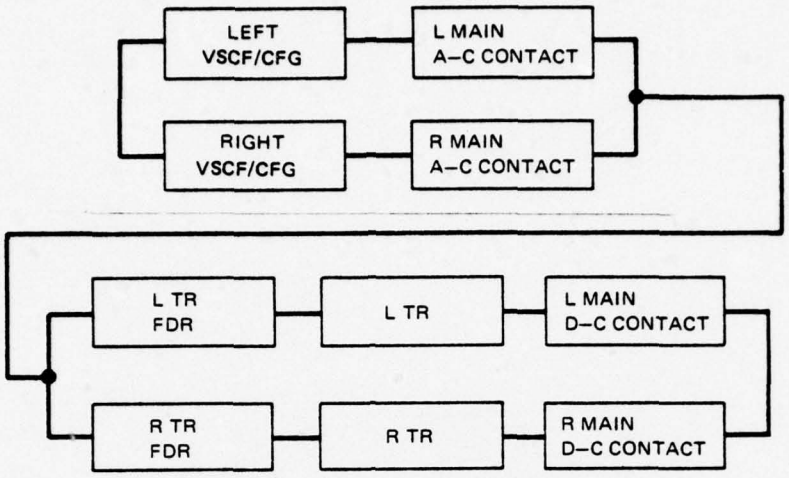


Figure 4-114. Reliability Model - AAES Power Generation Configuration IIB

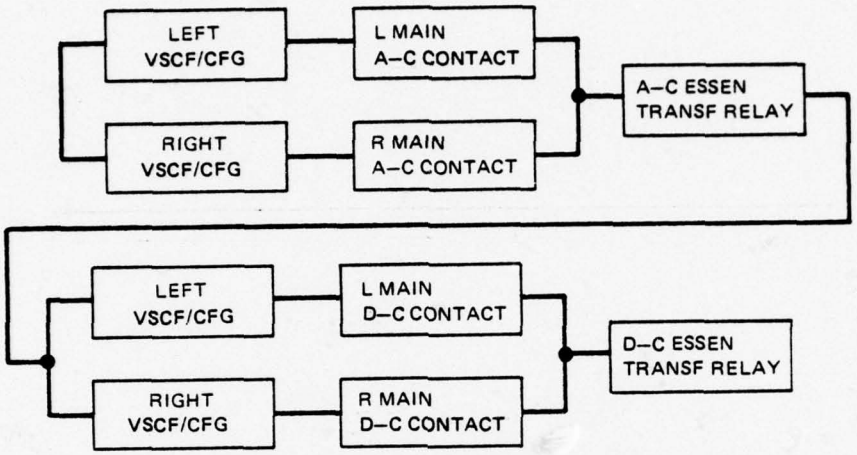


Figure 4-115. Reliability Model - AAES Power Generation Configuration IIIA

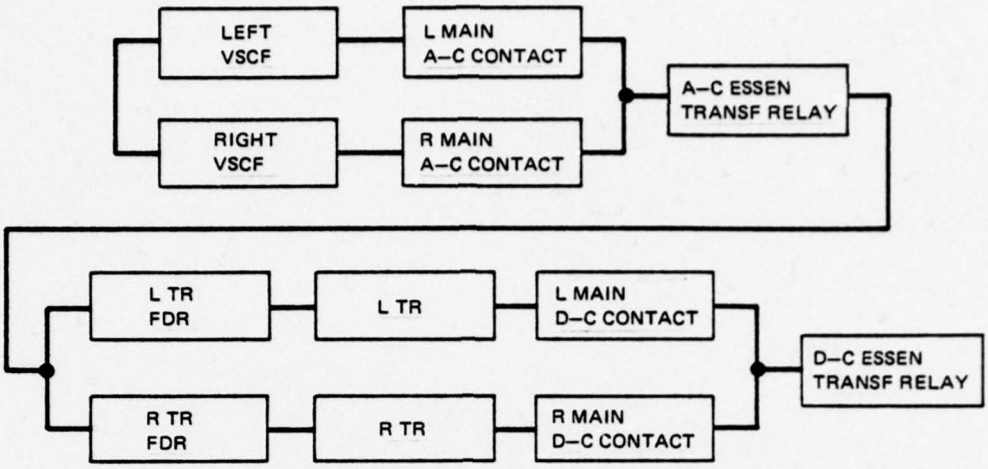


Figure 4-116. Reliability Model - AAES Power Generation Configuration IIIB

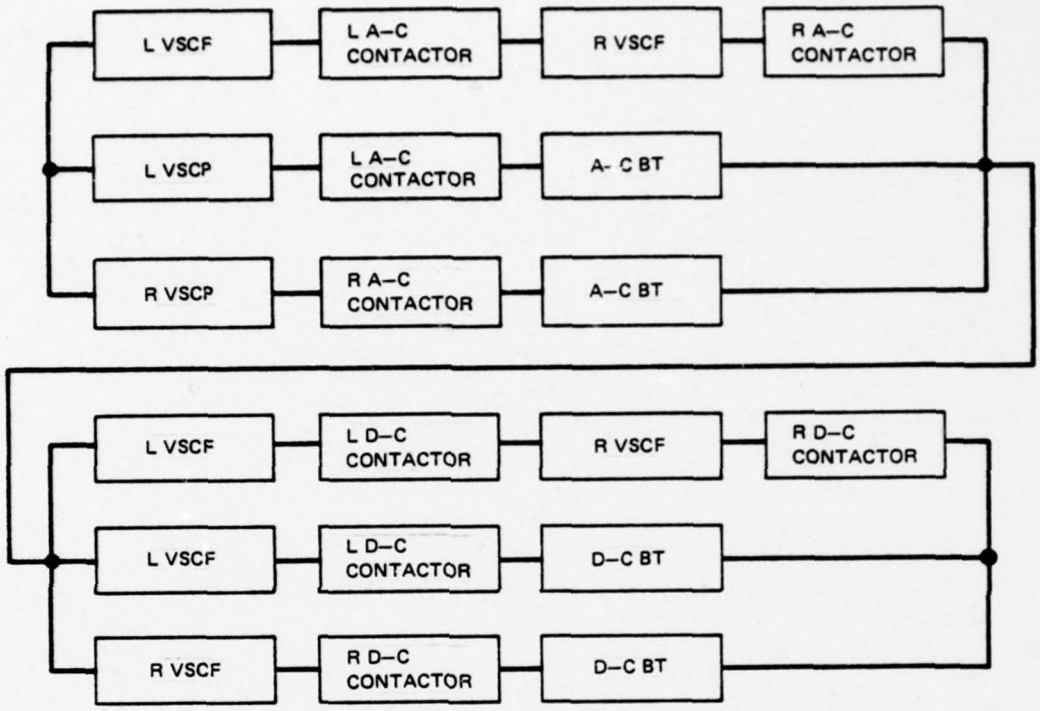


Figure 4-117. Reliability Model - AAES Configuration IVA

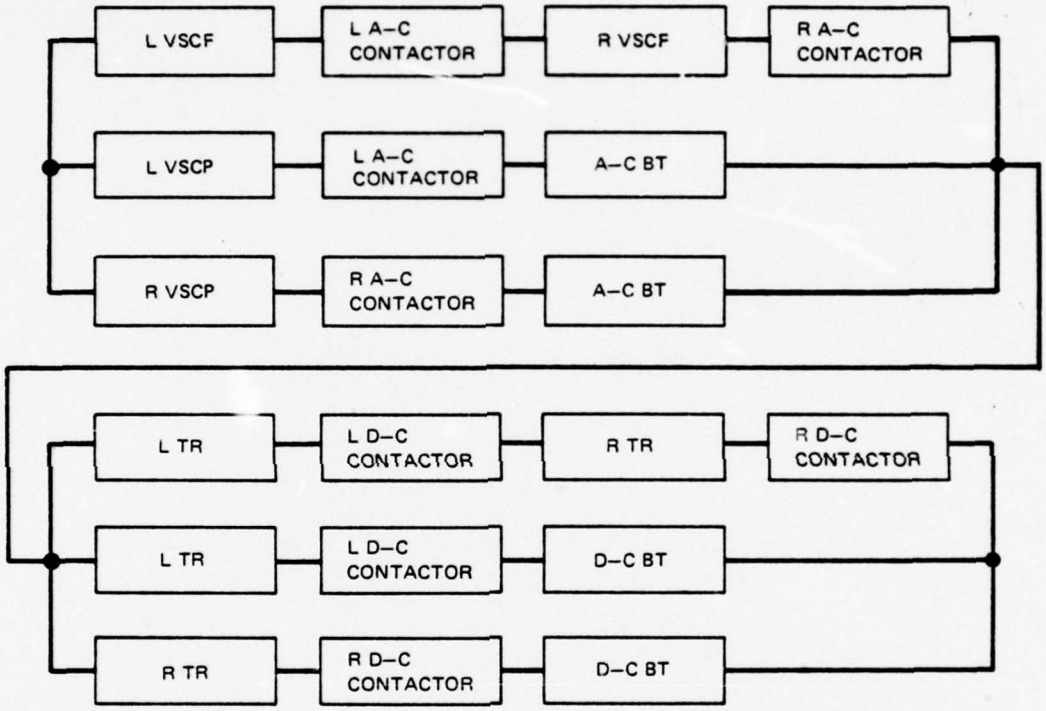


Figure 4-118. Reliability Model - AAES Configuration IVB

TABLE 4-51. CONFIGURATION STUDIED AND RESULTS

CONFIGURATION	MAIN AC SPLIT	MAIN AC //	ESSEN AC SPLIT	ESSEN AC //	MAIN DC SPLIT	MAIN DC //	ESSEN DC SPLIT	ESSEN DC //	TR	RELIABILITY	RANK
IA	X	X		X	X			X	INTEGRAL	.999709	3
IIB	X	X		X	X			X	SEPARATE	.999708	3
IIA		X				X			INTEGRAL	.999996	1
IIB		X				X			SEPARATE	.999997	1
IIIA		X		X		X		X	INTEGRAL	.999951	2
IIIB		X		X		X		X	SEPARATE	.999952	2
IVA	X	X			X	X			INTEGRAL	.999997	1
IVB	X	X			X	X			SEPARATE	.999997	1

MTBF's Used:

VSCF (75 kva CFG)	5,780 hr
Power Contactors	29,000 hr
Transfer Relays	222,222 hr
Feeder Circuit Breakers	1.6×10^6 hr
Separate T/R	6,440 hr

Mission Time = 5 hours

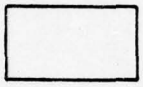
- Configuration IIB has been selected as the prototype system
- The Bendix MTBF estimate of 5780 hr for the CFG has been reduced by Grumman to 3000 hr to reflect a 70°C part ambient instead of the 25°C temperature assumed by Bendix.

The three-hour mission reliability was, therefore, recomputed for configuration IIB and equals 0.999998 while the mission MTBF is 3100 hr.

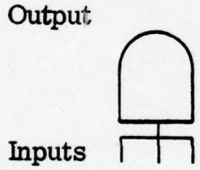
4.3.2.2 Fault Tree Analysis

A fault tree analysis was prepared to evaluate the impact of failures upon the flight test aircraft. This tree (Fig. 4-119) represents the possible combinations of failure (basic-events) which can create major power generation consequences.

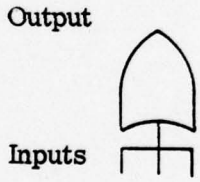
In the fault tree the following notation is used:



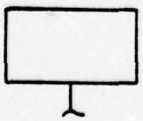
An event: Any failure occurence



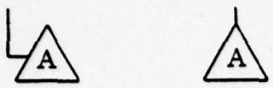
AND Gate: Output occurs if (and only if) all inputs occur



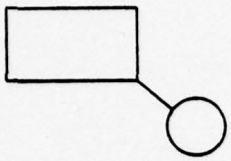
OR Gate: Output occurs if one or more of the inputs occur



Basic Event: Lowest order failure which has been identified. More detailed analysis is required to determine failure cause of basic event



Transfer Gate: Transfer to/from a branch repeated elsewhere



Monitor Point: Number in circle corresponds to instrumentation point indicating status of event, (refer to subsection 4.2.2, SOSTEL PGS monitor points).

The fault tree starts with the definition of the most undesired event (major PGS fault) and then determines, using the logic previously defined, the ways in which the system can fail so as to cause the event. The termination of a branch of the tree occurs when the event considered is a basic event or transfer gate.

Examination of the PGS fault tree reveals, with the exception of bus faults, that there is no continuous chain of OR gates between a major PGS fault and a basic event. This indicates that there are no single point failures (except bus failures) that can result in loss of any of the following:

- Right main a-c
- Left main a-c
- Essential a-c
- All a-c
- Right d-c
- Left d-c
- Essential d-c
- All d-c.

Additionally, the SOSTEL PGS monitor points that provide status of the events displayed in the tree are noted by a circle with a monitor point number indicated. These numbers, the signal name and signal source correspond to those listed in Table 4-30 of Subsection 4.2.2. In this way the fault tree can aid flight and ground

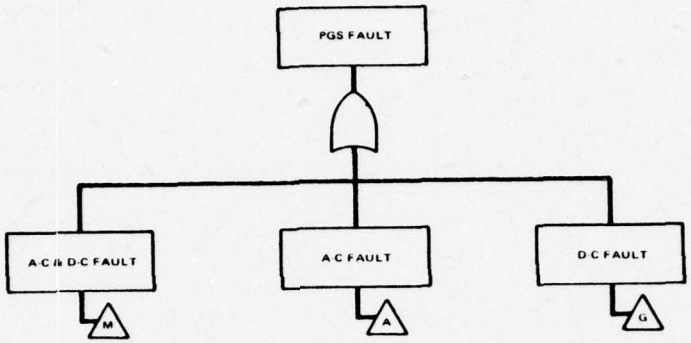


Figure 4-119. PGS Fault Tree (Sheet 1 of 4)

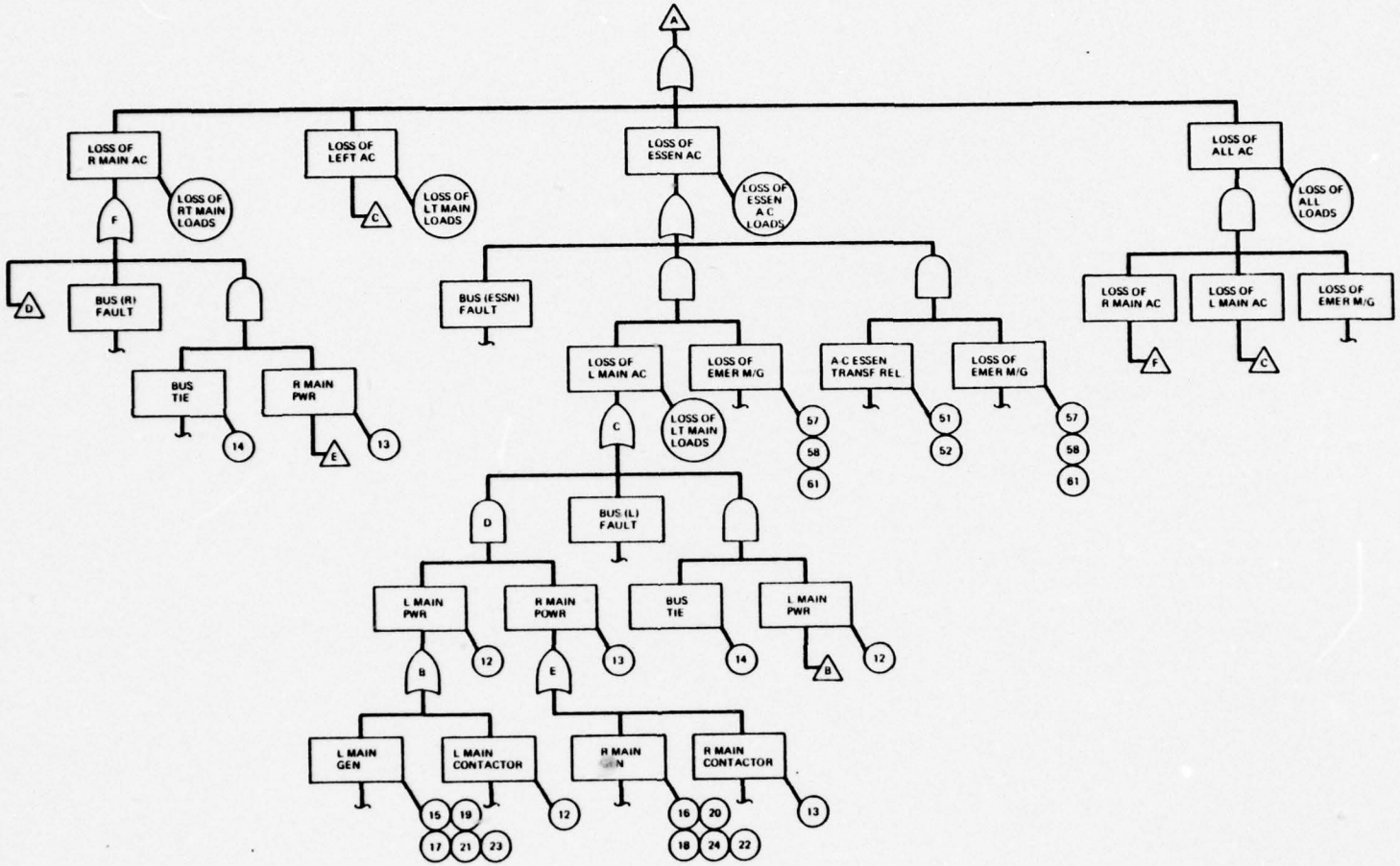


Figure 4-119. PGS Fault Tree (Sheet 2 of 4)

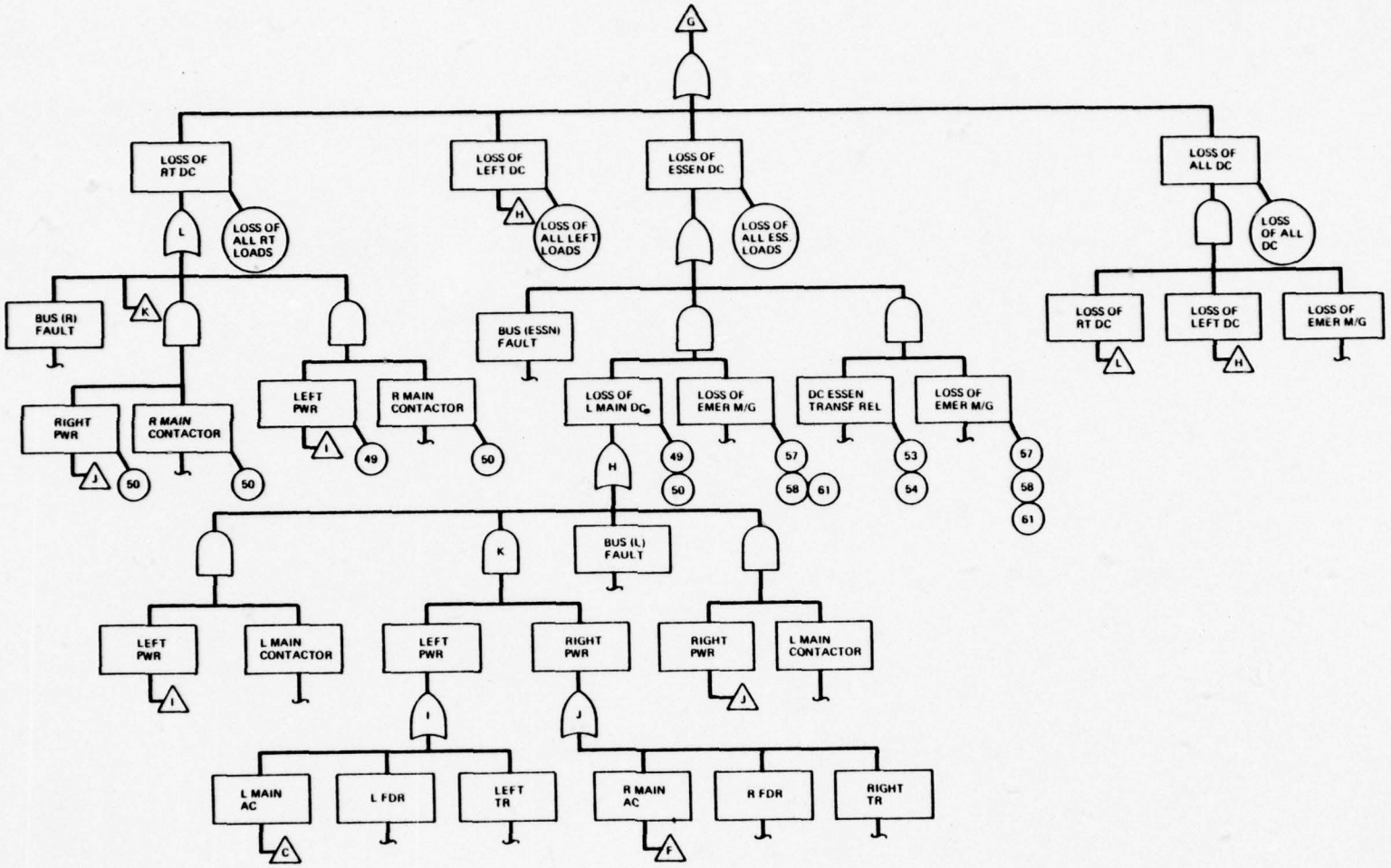


Figure 4-119. PGS Fault Tree (Sheet 3 of 4)

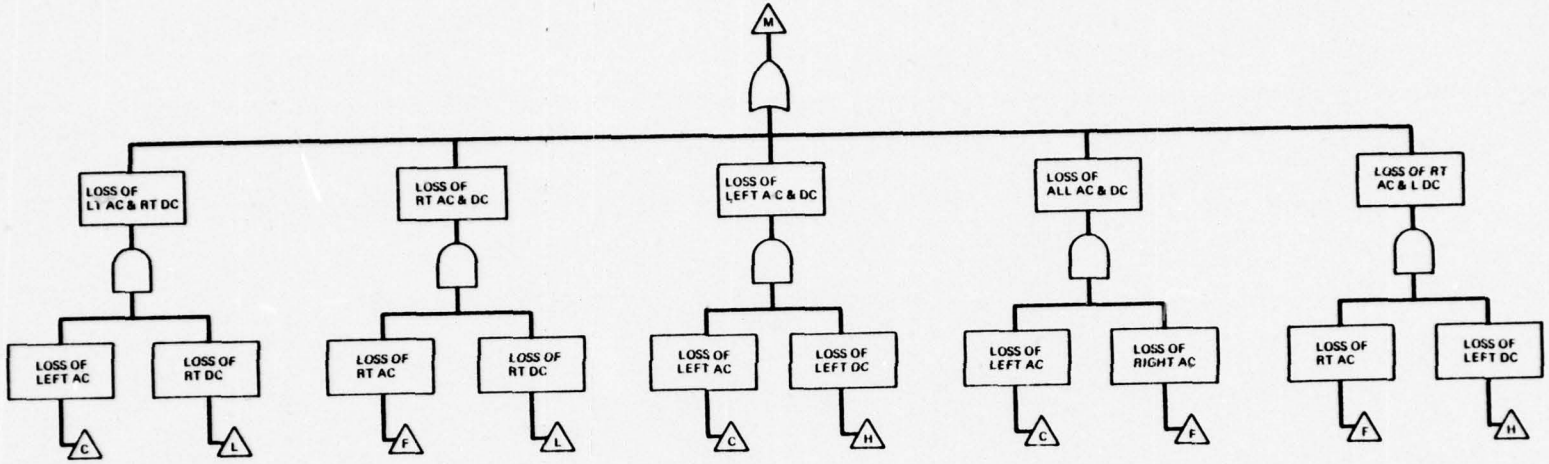


Figure 4-119. PGS Fault Tree (Sheet 4 of 4)

personnel to troubleshoot and isolate transient discrepancies and hardware failures.

4.3.3 SOSTEL CONTROL GROUP (OK171)

The SOSTEL equipments and their parameters that are pertinent to this analysis are listed in Table 4-50. The Grumman MTBF estimates are based on MIL-STD-271B using MIL-STD-883 Class B, established reliability, and JAN quality parts. Cost estimates were obtained by evaluating parts cost and multiplying by a factor of five for labor cost.

Since the MUX and DEMUX comprise approximately 80% of the system hardware it was decided to perform a cost benefit analysis on these components. The objective of a cost benefit analysis is to trade off the benefits (in terms of cost) of adding redundancy with the additional cost for the redundancy so as to arrive at a cost effective decision process. If we quantify the total benefits of adding redundancy in terms of cost of failure, C_F, and if we calculate the incremented increase in reliability, ΔR, when adding redundancy we can compute the expected value of savings when adding redundancy.

$$\text{Expected Savings} = \Delta R \cdot C_F$$

All reliability calculations were based on a three-hour mission. With the present utilization rate of 260 flight hours per year per aircraft a 10-year life cycle would result in 866 three-hour missions. Therefore, the expected life cycle savings over a 10-year period is

$$\text{Expected Savings} = \Delta R \times C_F \times 866.$$

This must be compared with the extra cost of redundancy, C_R.
For redundancy to "pay off".

$$\text{Expected Savings} > \text{Cost of Redundancy}$$

$$\Delta R \cdot C_F \cdot 866 > C_R$$

$$\text{OR } \frac{\Delta R}{C_R} > \frac{1}{C_F \cdot 866}$$

Using dynamic programming techniques the $\Delta R/C_R$ ratio, as well as the reliability versus delta cost for redundancy was computed for both MUX and DEMUX boxes. The analysis is based on a MUX and DEMUX configuration utilizing a "smart" terminal front end with a SOSTEL unique user I/O. The results are tabulated in Tables 4-52 and 4-53, and illustrated in Fig. 4-120 and 4-121. It was impossible at this time to obtain a number for the cost of failure, C_F. It was, therefore, decided to perform our analysis parametrically with C_F equal to 1%, 5% and 10% of the cost (C_I) of the equipment. These $\Delta R/C_R$ ratios form the basis for the redundancy decisions noted in Tables 4-52 and 4-53. As illustrated, internal redundancy was not justified for any of the internal components even under the conservative assumption that the cost of failure was equal to 10% of the total box cost. The maximum $\Delta R/C_R$ for both the MUX and DEMUX occurs in the processing section and is equal to $.36 \times 10^{-6}$. The first component in which redundancy is justified is the processor when the cost of failure, C_F, is:

$$\min C_F = \frac{1}{866 \times \max \frac{\Delta R}{CR}}$$

Redundancy was marginally justified only when the cost of failure, C_F, is unrealistically high and equal to 40% of the multiplexer cost and 26% of the demultiplexer cost.

The foregoing analysis did not consider the cost impact of reduced sparing that is required as a result of reliability improvement. Again it "pays" to add redundancy if -

Total Cost Without Redundancy > Total Cost with Redundancy

In this analysis, let:

C_I = cost of each unit without internal redundancy

N_I = number of baseline units

N_S = number of spares

C_{IR} = cost of each unit with internal redundancy

TABLE 4-52. $\triangle R/C_R$ RATIO FOR MULTIPLEXER

Equipment Name	$\triangle R/C_R$	$\triangle R/C_R > \frac{1}{C_T \times 866}$		
		$C_F = .01C_I$	$C_F = .05C_I$	$C_F = .1C_I$
Common	$.035 \times 10^{-6}$	N	N	N
DRVR/RCVR, MDR, BUF	$.078 \times 10^{-6}$	N	N	N
Process (4K Mem)	$.360 \times 10^{-6}$	N	N	N
Power Supply	$.124 \times 10^{-6}$	N	N	N
MUX/Current Source	$.0203 \times 10^{-6}$	N	N	N
Voltage Comparitor	$.0095 \times 10^{-6}$	N	N	N
Decoders	$.01125 \times 10^{-6}$	N	N	N
Bite	$.05714 \times 10^{-6}$	N	N	N
Control Counters	$.02071 \times 10^{-6}$	N	N	N

N = No Redundancy

Y = Add Redundancy

TABLE 4-53. $\Delta R/C_R$ RATIO FOR DEMULTIPLEXER

Equipment Design	$\Delta R/C_R \times 10^{-6}$	$\Delta R/C_R > 1/C_F \times 866$		
		$C_F = .01C_I$	$C_F = .05C_I$	$C_F = .1C_I$
Common	.035	N	N	N
DRVR/RCVR, MDR, BUF	.078	N	N	N
Processor (4K Mem)	.360	N	N	N
Power Supply	.124	N	N	N
MUX/Current Source	.02035	N	N	N
Voltage Comparitor	.0095	N	N	N
Decoders	.01125	N	N	N
Bite	.0574	N	N	N
Control Counters	.0207	N	N	N
Current Drivers	.0495	N	N	N
64 Bit Storage	.0297	N	N	N

N = No Redundancy

Y = Add Redundancy

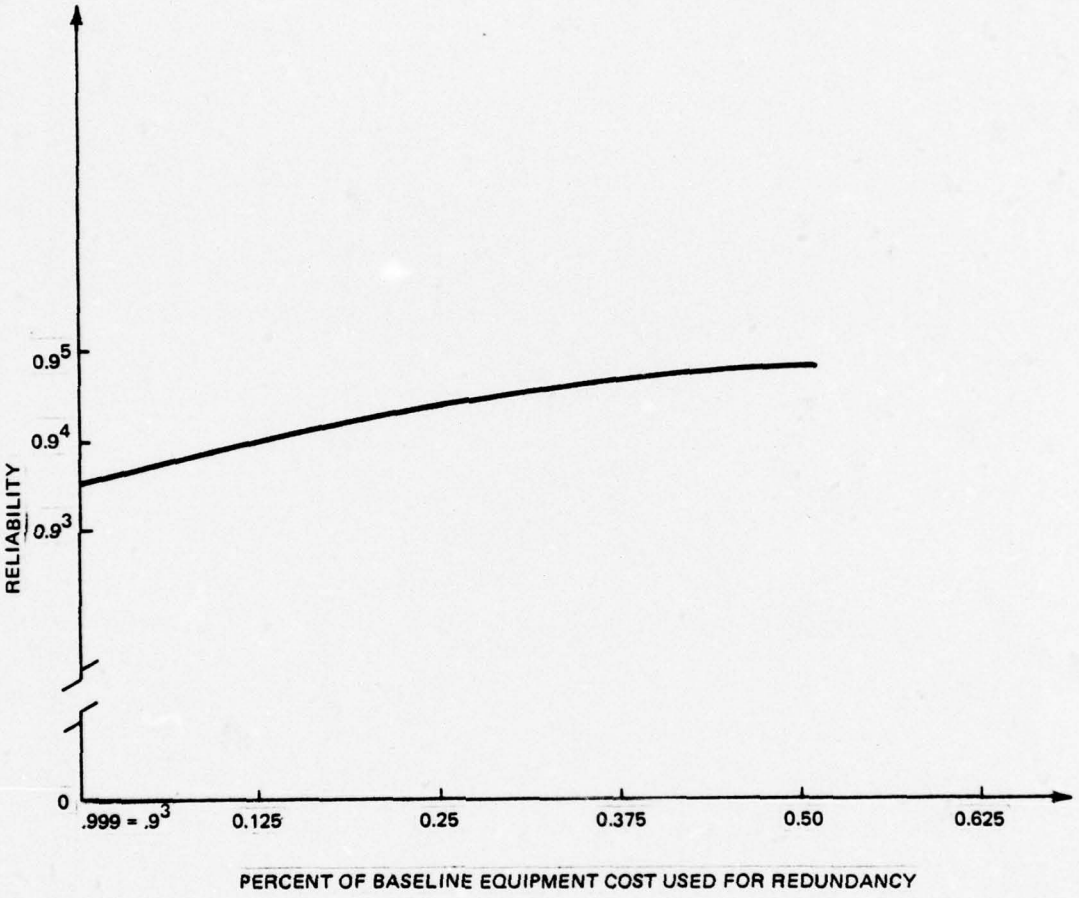


Figure 4-120. SOSTEL Multiplexer Reliability Vs. Delta Cost for Redundancy

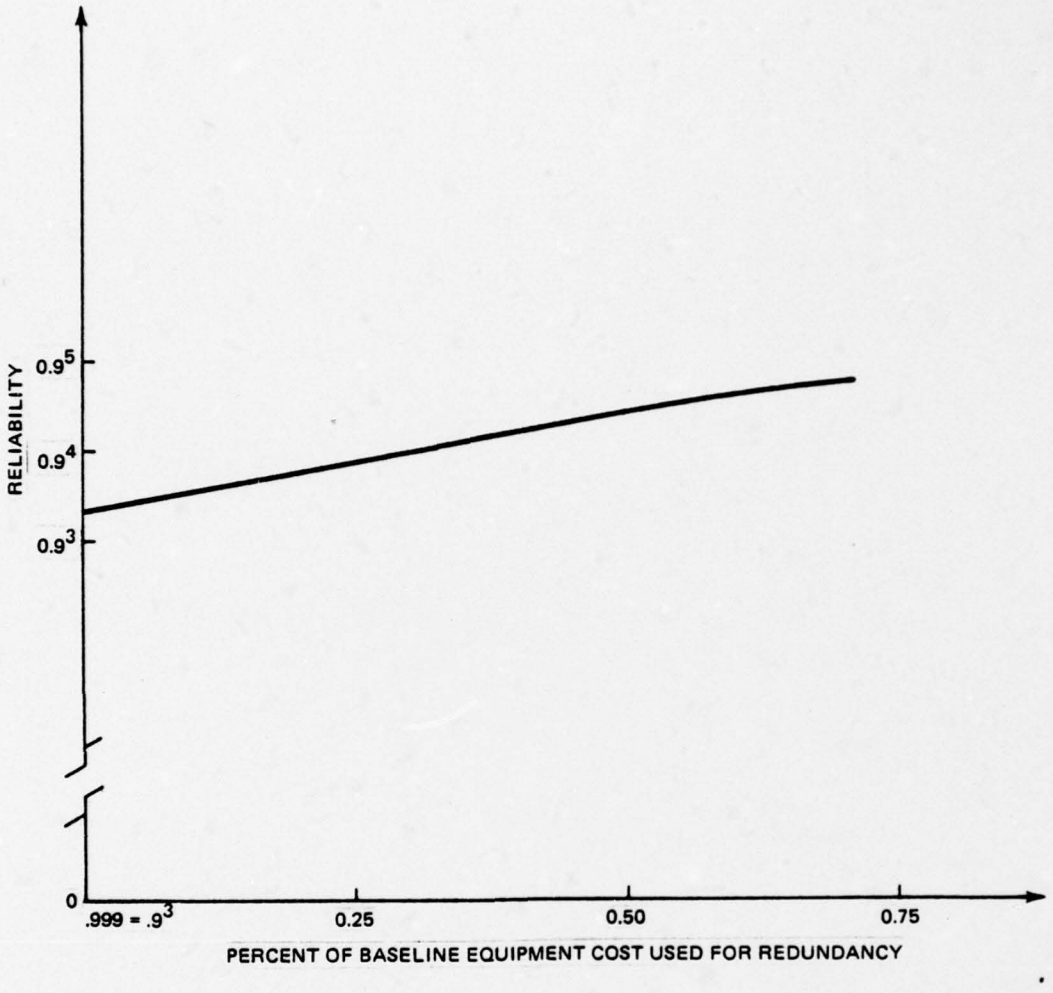


Figure 4-121. SOSTEL Demultiplexer Reliability Vs. Delta Cost for Redundancy

N_{IR} = reduced number of spares because of internal redundancy

ΔC = delta cost of each unit to incorporate internal redundancy.

Therefore,

Total Cost Without Redundancy > Total Cost With Redundancy

$$(N_I + N_S)\, C_I > (N_I + N_{IR})\, C_{IR}$$

Since $C_{IR} = C_I + \Delta C$

$$(N_I + N_S)\, C_I > (N_I + N_{IR})\, (C_I + \Delta C)$$

$$(N_I + N_S)\, C_I > (N_I + N_{IR})\, C_I + (N_I + N_{IR})\, \Delta C$$

$$(N_I + N_S) > (N_I + N_{IR}) + \frac{\Delta C}{C_I}\, (N_I + N_{IR})$$

If the above inequality holds it "pays" to add redundancy.

First consider the MUX with a MTBF of 4550 hr (failure rate = 219×10^{-6}). Let N_I, the baseline number of units, equal 4000 (400 ship sets). Assume a six-month spare turnaround time, from time of failure to when a box is returned to stock.

The expected flight operating time for these equipments in that six-month period is equal to one-half the present yearly utilization rate of 260 hr. Therefore, the expected number of failures in the MUX in this period is equal to

$$\text{Expected No. of Failures} = N_I \times \lambda \times t$$

$$= 4000 \times 219 \times 10^{-6} \times 130$$

$$= 113.8$$

Letting the expected number of spares equal the expected number of failures we have $N_S = 114$. By adding 27.5% of the baseline cost, C_I, for redundancy, the MTBF can be increased to 9850 hr (failure rate = 101×10^{-6}) so that the expected number of failures for units with internal redundancy is

$$\text{No. of Failures} = N_I \times \lambda \times t$$

$$= 4000 \times 101 \times 10^{-6} \times 130$$

$$= 52.5$$

Therefore, the reduced number of spares N_{IR} is equal to 53.

Now substituting into the inequality

$$(N_I + N_S) > (N_I + N_{IR}) + \frac{\Delta C}{C_I} (N_I + N_{IR})$$

$$(4000 + 114) > (4000 + 53) + .275\ (4000 + 53)$$

$$4114 > 4053 + 1195$$

$$4114 \not> 5248$$

We see that the inequality does not hold. Adding internal redundancy while reducing spares requirements results in larger total cost.

Similarly, for the DEMUX, 400 ship sets requires 2800 baseline units with an MTBF of 3650 hr (failure rate = 275×10^{-6}).

The required number of spares is equal to the expected number of failures.

$$\text{Expected failures} = N \times \lambda \times t$$

$$= 2800 \times 275 \times 10^{-6} \times 130$$

$$= 100.1$$

Therefore, $N_S = 101$ spare units. By adding 39% of the baseline cost C_I for redundancy the MTBF can be increased to 8660 hr or a failure rate of 115×10^{-6}. With this added redundancy the required numbers of spares is N_{IR}

$$N_{IR} = 2800 \times 115 \times 10^{-6} \times 130$$

$$N_{IR} = 42$$

Again substituting into the inequality.

$$(N_I + N_S) > (N_I + N_{IR}) + \frac{\Delta C}{C_I} (N_I + N_{IR})$$

$$(2800 + 101) > (2800 + 42) + .39\ (2800 + 42)$$

$$2901 > 2842 + 1108$$

$$2901 \not> 3950$$

Again, the inequality does not hold and internal redundancy for the DEMUX cannot be justified based on reduced spares requirements.

Finally, since internal redundancy is not cost effective from a cost of failure and reduced sparing viewpoint for the MUX and DEMUX, the impact of internal redundancy upon mission success must be examined. Two configurations were examined: with no internal redundancy and with limited internal redundancy. For these two configurations, a system reliability versus delta cost curve was generated in which reliability was increased by adding additional equipments (black boxes). Dynamic programming techniques were again used so as to obtain maximum increases in reliability for a given cost. The results of this analysis is illustrated in Fig. 4-122 and shows insignificant gains in mission reliability for excessive cost expenditures. It should not be concluded from the above that redundant boxes are not required for flight safety or other nonquantitative operational requirements. What can be concluded is that mission reliability (in numerical terms) is not significantly enhanced by excessive expenditures for internal redundancy in the MUX or DEMUX units.

4.3.4 SOLID STATE POWER CONTROLLERS (SSPC)

There are approximately 400 loads that required SSPC's in a full-up AAES system for the F-14. Therefore, the reliability of the SSPC will be a significant contributor to aircraft availability and life cycle cost. It was decided to perform an independent evaluation of the MTBF of a typical SSPC and, if possible, determine the reliability drivers.

For this purpose a five amp d-c RCA design (Contract No. N62269-72-C-0642, 8/8/75) illustrated in Fig. 4-123 was evaluated, and Method 2.1.7 of MIL HBK 217B used to determine the SSPC MTBF.

The hybrid failure rate model is:

$$\lambda_p = \lambda_b (\pi_\tau \times \pi_E \times \pi_Q \times \pi_f) \text{ failures } /10^6 \text{ hr}$$

where:

λ_b = base failure rate

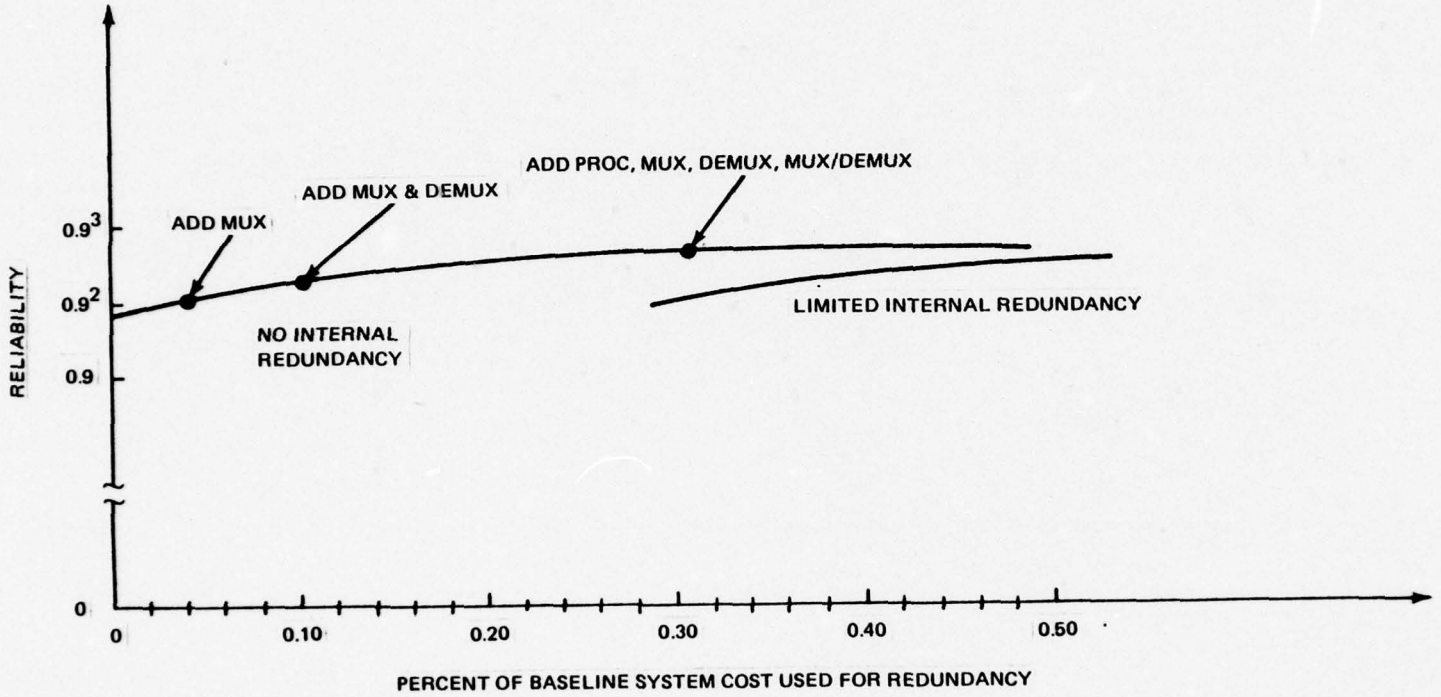
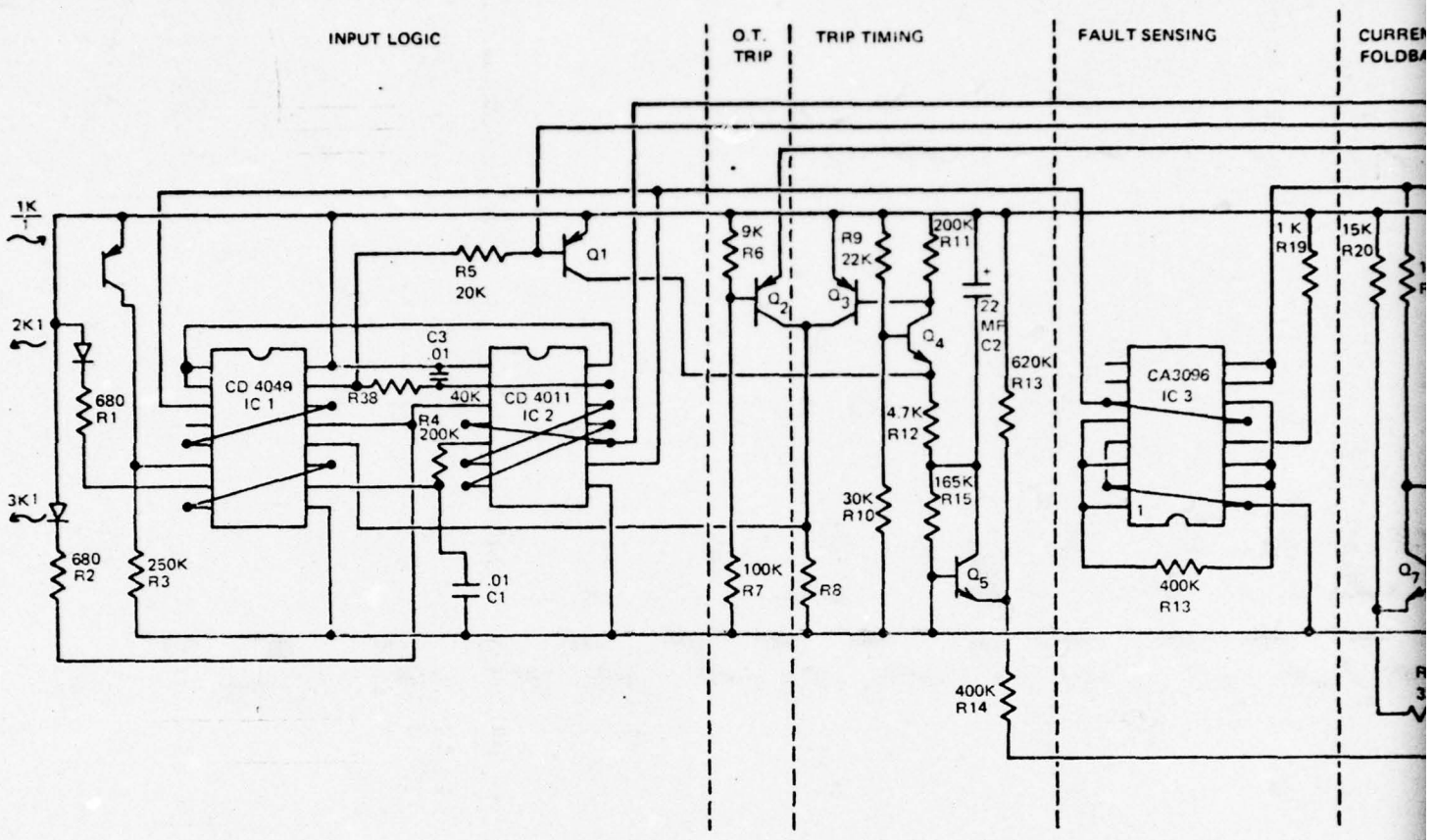


Figure 4-122. SOSTEL System Reliability Vs. Delta Cost for Redundancy With Degree of Internal Box Redundancy as a Parameter



NOTE: 1. * – ACTIVE TRIM FOR CURRENT LIMIT – 14K NOMINAL
2. ALL I.C.S. – BOTTOM VIEW

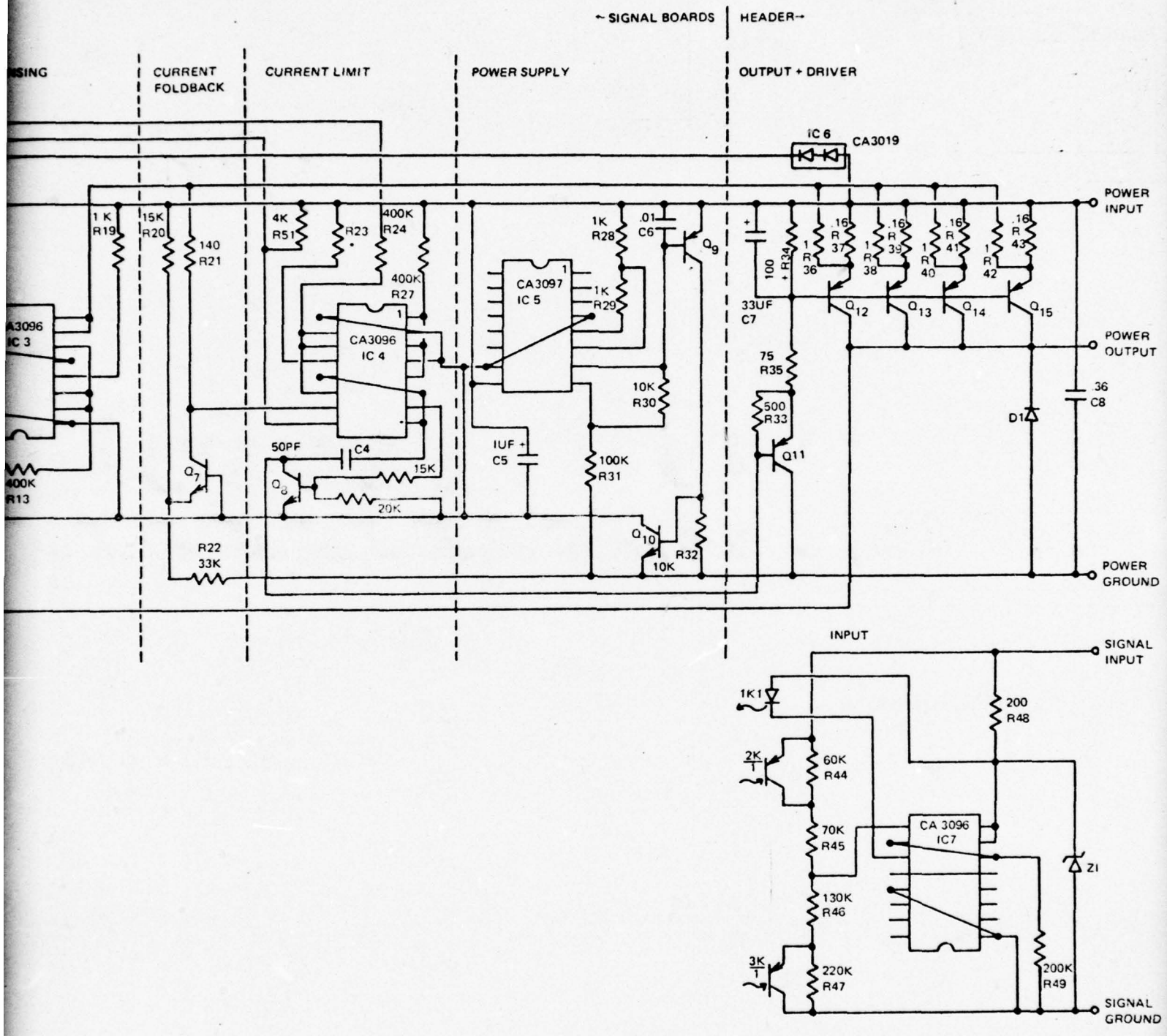


Figure 4-123. RCA Power Controller

π_T = temperature factor

π_E = environmental factor = 6.0 for airborne uninhabited environment

π_Q = quality factor = 0.5 (highest quality)

π_f = 1.1 for linear-digital combination hybrids

λ_b is composed of contributions from the following areas

λ_b = substrate + complexity + film resistors + attached components + package

These were evaluated using MIL HBK 217B, and the failure rates that result ($X10^{-6}$) are

- Substrate = 0.04
- Complexity = 0.00314
- Film resistors = 0.024
- Attached components = 1.28
- Package = 0.05

1.39714

The largest contributor to the baseline failure rate are the attached components but at this time it is appropriate to assume that the parts count cannot be significantly altered. However, future study should consider a reduced parts configuration and the possibility of removing the LED's from the design. The three LED's used in the BIT circuits account for approximately one-half of the attached component failure rate. However, these LED's are probably peculiar to this RCA design and should not be a consideration for determining the MTBF drivers for SSPC's in general. Recalling our generalized hybrid failure rate model

$$\lambda_p = \lambda_b (\pi_T \times \pi_E \times \pi_Q \times \pi_f)$$

The terms π_E and π_f are fixed values and cannot be altered; that is, the environment must be airborne uninhabited ($\pi_E = 6$) and the circuit function is linear digital ($\pi_f = 1.1$). Therefore,

$$\lambda_p = 1.39714 (\pi_T \times 6 \times \pi_Q \times 1.1)$$

The term π_Q, which is the quality factor, will either be .5 or 1 for high reliability and military devices. Assuming $\pi_Q = 0.5$

$$\lambda_p = 1.39714 \ (\pi_T \times 6 \times .5 \times 1.1)$$

The term π_T, which is the temperature factor, equals one for a case temperature of 25°C or 16 at a case temperature of 120°C. Therefore, the largest driver by far for a SSPC is temperature. In this case,

$$\lambda_p = \pi_T \times 4.610562$$

For various temperatures, λ_p was computed and the associated SSPC MTBF ($1/\lambda_p$) was plotted. These results are shown in Fig. 4-124, and illustrate the significant impact temperature has upon SSPC MTBF. Active cooling for SSPC's should, therefore, be investigated and a cost/benefit analysis performed to determine the desirability of reducing the SSPC temperature.

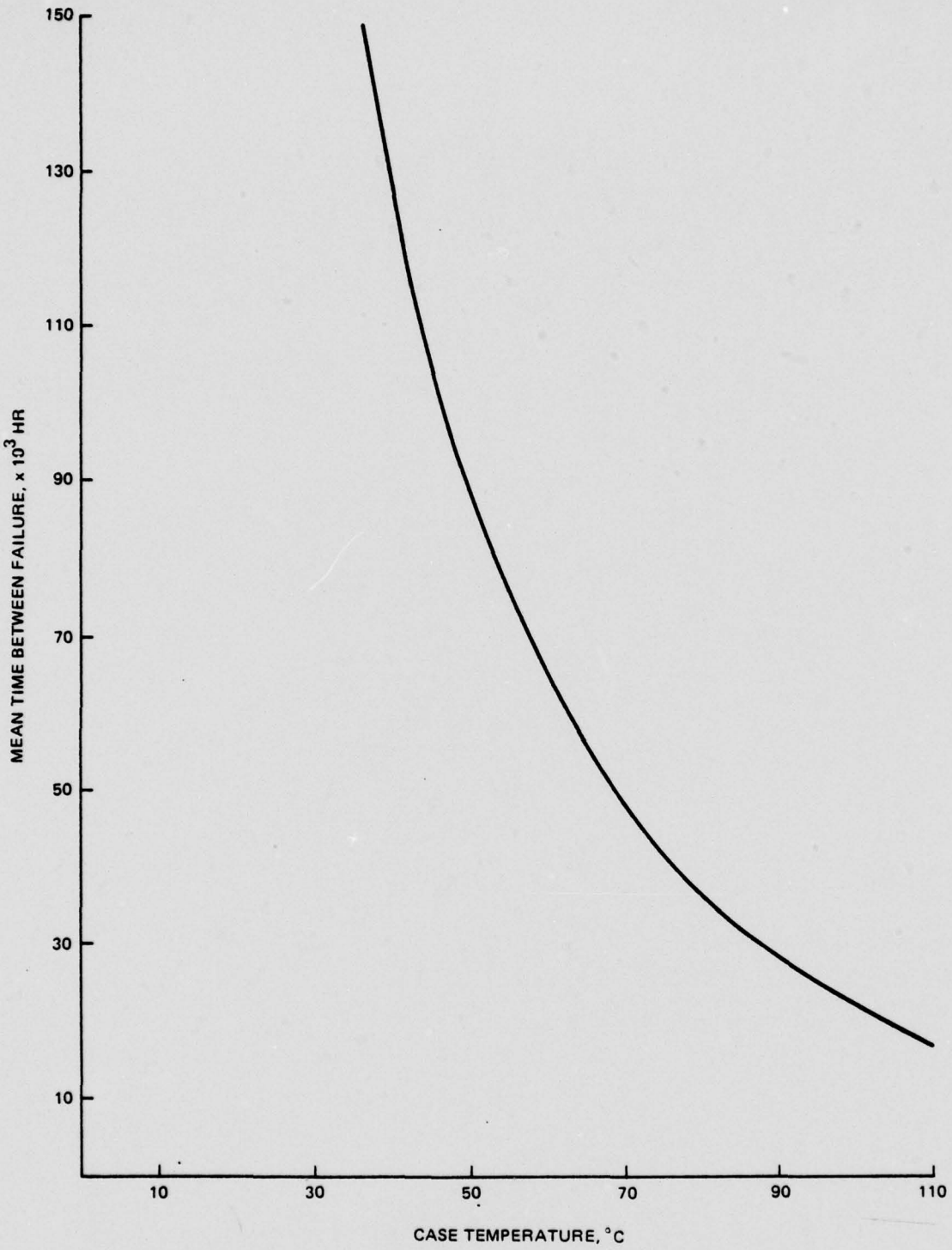


Figure 4-124 MTBF Vs. Case Temperature for RCA 5-A, 28-VDC Solid State Power Controller

4.4 AAES FLIGHT TEST PROGRAM

4.4.1 TEST PHILOSOPHY

The AAES installed in the test bed aircraft will undergo extensive ground testing to verify basic system operation and confirm that the system is ready for flight testing. Ground tests will be performed which will stress the AAES more severely than the testing planned in flight. For example, the CFG output will be applied to a load bank with the capacity to load the generator to its full rated output. The generator will be operated at full load at extremes of its operating rpm range. The ground testing will emphasize load management in simulated failure modes to provide confidence in the system from a flight safety viewpoint. The first flights of the aircraft will be primarily to evaluate basic system operation and will be conducted under benign flight conditions. After confidence in the system is established, operating conditions will progress to the most severe.

4.4.2 FLIGHT TEST CONSTRAINTS

Any attempt to conduct airborne testing to extremes of the AAES operating conditions (full rated load, extremes of power factor, load switching for transient response investigation, etc) is considered unjustifiable from the viewpoint of cost and risk. The cost factor arises from the special test equipment and instrumentation which would be installed in the test bed aircraft. Special equipment would include a load bank with 75 kva capacity, switching to allow step load changes between 10% and 90% of full rated capacity, load reactances to allow a variable power factor, and sufficient shielding, air flow, (ECS requirements for a load bank cooling have not been evaluated) and insulation to cope with the heat generated by a 75 kva load. Additional instrumentation would include a wide band analog system for transient response and d-c ripple recording. The risk involved arises from the heat generated by the load bank. A hot load bank could be an extreme hazard during crash and rescue operations. It would also be hazardous to ground maintenance personnel. Therefore, testing to the extent required to show complete compliance with MIL-STD-704 type power characteristics will be performed in the laboratory only.

4.4.3 FLIGHT SAFETY CONSIDERATIONS

Safety of flight aspects of AAES operation in a test bed aircraft are covered in Subsections 3.4, and 4.2.2. The low priority of the loads to be controlled by SOSTEL, plus the load shedding and failure switching concepts combined with initial PGS backup by the remaining IDG generator and emergency generator shows the operation of the proposed test bed installation to involve no significant risk in airborne operation which would result from failures or anomalous operation of AAES components. After initial flights establish confidence in the system, the backup IDG can be replaced by another CFG. Temperatures of critical components will be monitored and displayed real time in the cockpit, allowing the air crew to abort a test and take corrective action in case of an overheat condition.

4.4.4 FUNCTIONAL TEST REQUIREMENTS

The test objectives and test methods applicable to the evaluation of the AAES as installed in the test bed aircraft with respect to the following broad operational parameters are:

- Steady-state electrical characteristics
- Operating temperatures of generators, conversion and power distribution equipment
- Fault protection and load management adequacy
- EMC between AAES and installed avionics
- Functional suitability of AAES controls and displays.

These tests are designed to produce data which will be taken during ground tests and all phases of the aircraft mission profile. Testing will be as thorough as possible in view of the less than complete AAES installation in the proposed test bed.

4.4.4.1 A-C and D-C Power Capacity and Steady-State Performance

4.4.4.1.1 Test Objective

Evaluate the AAES capacity for generation and conversion of full rated electrical power under all engine speeds from minimum ground idle to maximum rpm. Show that voltages and frequency remains within tolerance over the full rpm range. Show voltage and frequency sensing and control to be adequate to allow the buses to be paralled under extreme mis-match in engine rpm.

4.4.4.1.2 Test Method

Full rated power tests will be performed under engine power during ground tests only. Electrical load will be provided by an external load bank. Airborne testing will primarily utilize the loading capacity of the aircraft systems.

Tests will be performed on a ground run and at various flight conditions during the following flight profile: takeoff, climb, level flight (sea level, 15,000 ft, 30,000 ft, and service ceiling) at minimum and maximum rpm, level flight at 40,000 ft with N_2 rotor speed at 81.7%, idle power descent, approach, and landing. A typical flight profile is illustrated in Fig. 4-125.

Data will be recorded on an on-board instrumentation system during the flights with the buses in the split configuration and maximum load on the CFG and during a-c and, if applicable, d-c bus switching between split and parallel configuration with engine rpm-matched and mismatched.

4.4.4.2 Operational Temperatures

4.4.4.2.1 Test Objectives

Evaluate AAES component temperatures while system is operated at a maximum possible loads and during extremes of flight conditions.

4.4.4.2.2 Test Method

Data will be recorded with maximum possible loading to produce the greatest possible electrical stress and consequently the highest operating temperatures. Full

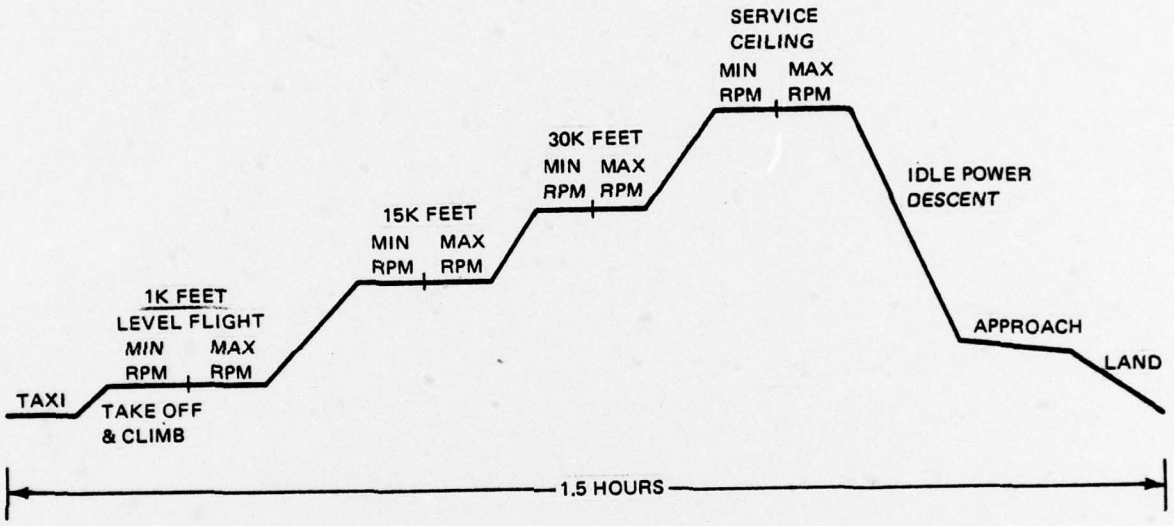


Figure 4-125. Typical Flight Profile

rated loads will be achieved under engine power on the ground using a load bank. Temperatures noted during ground runs will, if within acceptable tolerances, be sufficient to clear the system for in-flight testing. Airborne power loading will be that achievable utilizing avionic loads. Flight profile will be that described previously.

4.4.4.3 Fault Protection and Load Management

4.4.4.3.1 Test Objective

Evaluate the adequacy of fault detection and protective switching controls and display of fault conditions.

4.4.4.3.2 Test Method

The fault protection and detection systems and protective load switching through SOSTEL will be completely evaluated in the laboratory. Special test equipment capable of stimulating overvoltage, undervoltage, overfrequency, underfrequency and overcurrent conditions will be used to flex all aspects of the fault protection circuitry. In-flight failure mode evaluation will be limited to operating normal cockpit PGS control switches to simulate generator and d-c supply failures.

After the complete evaluation of the SOSTEL functions in the laboratory, it is not justifiable to provide the extensive aircraft instrumentation which would be required to objectively examine the complete SOSTEL operations while airborne. Evaluation data will be in the form of aircrew comments on the ICS recording.

4.4.4.4 Electromagnetic Compatibility

4.4.4.4.1 Test Objective

To evaluate EMI between AAES and existing aircraft avionics. AAES will be evaluated both as source and victim of EMI.

4.4.4.4.2 Test Method

Concurrently with all other phases of AAES flight testing, as many combinations of AAES and avionic mode switching will be conducted as practical. Evaluation of

EMI affects will be subjective as perceived through observation of AAES and avionic operation. Results will be noted on ICS recording.

4.4.4.5 Functional Suitability of AAES Controls and Displays

The test method for aircrew evaluation will be subjective, and will be continuous throughout all phases of in-flight testing. The aircrew will note any human factor incompatibilities as manifested through normal system usage during in-flight conditions.

4.4.5 AAES DATA REQUIREMENTS

4.4.5.1 Supportive Data

Basic aircraft flight data are required for correlation with electrical evaluation data. Flight data are of the type such as Mach No., altitude, OAT, and engine rpm. Data directly required to support each test objective will be described in this paragraph under the applicable test objective heading.

4.4.5.2 A-C and D-C Power Capacity and Steady State Performance

The following data will be obtained:

- Airspeed
- Altitude
- Left and right engine rpm
- A-C frequencies and amplitudes
- D-C amplitudes
- Phase angle with respect to phase A of phases B and C of CFG output
- Phase angle between phases A, B and C of CFG and phases A, B and C of conventional generator
- Delta amplitude between respective phases of CFG and conventional generator outputs

- Delta amplitudes between the two 28 vdc sources
- A-C and if applicable, D-C bus state (split or paralleled)
- A-C and d-c current loads.

Data will be recorded for a nominal five-minute time slice of each test condition, after allowing time for conditions to stabilize.

Plots will be prepared which will show:

- Frequency deviation from its nominal value as functions of engine rpm and load
- A-C and d-c amplitude deviation from nominal as a function of engine rpm and load
- Phase angles between the three CFG output phases as a function of engine rpm and load
- Phase angle and amplitudes between phases A, B and C of CFG and phases A, B and C of conventional generator for time slice including switching to parallel bus configuration
- Delta amplitudes between the two 28 vdc buses if applicable, including switching to parallel bus configuration.

4.4.5.3 Temperatures

A tabulation of AAES temperatures will be obtained for each test condition. Each test condition will have been maintained for a sufficient period of time for temperatures to stabilize. Test conditions will consist of combinations of airspeed, altitude, engine rpm, and electrical load. Test conditions will be noted on the tab.

4.4.5.4 Vibration Environment

Power spectral density plots will be produced for the severe vibration environ-

4.4.6 AAES FLIGHT TEST INSTRUMENTATION

The cross-over point in the cost of an instrumentation system consisting of FM analog and a hybrid FM/PCM system is based on the number of parameters to be recorded, and is found to occur somewhere between 50 and 100 parameters. The suggested list of AAES instrumentation totals 67 parameters. An all-PCM system is not feasible because of the higher frequency response required by the vibration measurements. In this case, since the cost of either a hybrid or an analog system is roughly similar, the choice of the type of system could be determined by the type of ground data processing equipment the flight test organization chooses to use.

The suggested list of parameters to be recorded in-flight follows:

- IRIG time
- ICS voice
- Airspeed
- Altitude
- Mach
- OAT
- Left and right engine rpm
- 4 a-c frequencies
- 6 a-c amplitudes
- (2) 28 vdc amplitudes
- (2) 270 vdc amplitudes
- 2 phase angles (phases B & C, with respect to phase A of CFG output)
- 3 phase comparisons (phase A to A, B to B, C to C of CFG output and conventional generator output)

- 3 a-c amplitude comparisons
- (1) 28 vdc amplitude comparison
- 2 bus state discretes
- 3 a-c current loads
- (1) 270 vdc current load
- (2) 28 vdc current loads
- 20 temperatures
- 10 vibrations

Instrumentation will also provide a cockpit display for four temperatures.

4.4.7 REQUIRED FLIGHTS

Three categories of flights are necessary: functional check flights after the prototype system installation, buildup from benign to more severe flight conditions, and full profile tests. Numbers of flights are:

- 3 flights for post installation shakedown and functional integration
- 3 flights to build up to severe conditions
- 5 flights for full profile testing.

Flight test experience has shown the necessity of including a 50% contingency factor in planning the number of flights required to achieve the program goals. Therefore, a total of 16 flights must be planned for the AAES program. The five full-profile flights will be completely redundant. The purpose is to show repeatability and to avoid statistical anomalies. Two ground tests under engine power will also be performed.

4.4.8 SELECTION OF A TEST BED AIRCRAFT

A comparison of candidate aircraft for the AAES test bed is illustrated in Table 4-54. The selection of a test bed aircraft is determined by three basic criteria:

TABLE 4-54. Comparison of Candidate Aircraft for AAES Test Bed

Aircraft	Multi-Engine	Advanced Aircraft Environment		Present Generating Capacity	Navy Asset	Familiar to Study Contractor	Aircraft Volume
		Supersonic (1.6 + M)	High g (4 + g)				
S-3	Yes	No	No	120 kva	Yes	No	Large
A-6E	Yes	No	Yes	60 kva	Yes	Yes	Medium
EA-6B	Yes	No	Yes	60 kva	Yes	Yes	Medium
E-2C	Yes	No	No	180 kva	Yes	Yes	Large
F-4J	Yes	Yes	Yes	60 kva	Yes	No	Medium
A-7	No	No	Yes	25 kva	Yes	No	Small
P-3	Yes	No	No	270 kva	Yes	No	Large
F-14	Yes	Yes	Yes	150 kva	Yes	Yes	Medium
F-15	Yes	Yes	Yes	80 kva	No	No	Medium
F-16	No	Yes	Yes	40 kva	No	No	Small

multi-engines, a severe operating environment, and a diverse suite of avionics and systems providing a relatively high steady-state electrical load. The rationale for these basic requirements are explained as follows:

- A multi-engine aircraft is a requirement from a flight safety viewpoint. It allows the installation of one prototype generator while retaining a conventional generator for a backup to assure the capability to supply power at least to flight essential avionics in the event of prototype system failure. Subsequent installation of a second prototype generator can be accomplished after confidence is established, and if additional operational information is required. Another consideration requiring a multi-engine aircraft is the ability to investigate the operational capability of split synchronizing two power sources and to allow the power buses to be paralleled

- Severe environment testing is required to investigate the suitability for use of the AAES on high performance aircraft - particularly aircraft of the future. A fighter-type aircraft would present the most severe operating environment in the form of g loads, aerodynamic heating, and engine transient effects

- The candidate aircraft should have a diverse suite of avionics to provide a range of loading to assess the response characteristics of power control functions. The avionics and other systems should provide a load which will allow the prototype generator to be operated at well over 50% of its rated capacity. The load should include significant motor loads.

The choice of a test bed aircraft is, therefore, quite limited. The multi-engine fighter requirement restricts the choice, in the current Navy inventory, to the F-4 and the F-14. Of these, the F-14 is the choice based upon its ability to load the generating system. The maximum electrical load on the generating system, under steady state conditions, but without operating the flight control backup module, is approximately 70 kva. Furthermore, the AWG-9 system, when switched from standby to the highest power transmitting mode, results in a step change in load of 21.2 kva.

This step change in system load is sufficient to note transient effects under actual operating conditions. In addition, the flight control backup module is a dydraulic pump driven by a two-speed, three-phase motor. In high and low speed modes, the motor draws 11.6 and 7.5 kva, respectively. This is a significant motor load which may be applied in flight under cockpit control.

Further considerations in favor of the F-14 is that the instrumentation system, and prototype hardware, may be mounted in the volume made available by removing the ammo drum. There is, therefore, no requirement to remove any avionics. And, naturally, an aircraft familiar to the contractor, with the ready availability of all pertinent drawings, and in which the contractor has already installed instrumentation systems, would be preferred to minimize the cost impact.

Section 5

CONCLUSIONS AND RECOMMENDATIONS

The F-14A aircraft is an ideal medium for the demonstration of the AAES concept. This high performance two-engine aircraft provides backup capability with the present IDG for power generation and its multibus configuration when a single CFG - d-c link or VSCF generator is installed for a flight test of AAES. This approach provides a normal evolution for the installation of a second generator after flight confidence in the equipment is established. There are no serious mechanical or thermal problems associated with the installation of AAES components (PGS or SOSTEL) in any of the flight test configurations. Alternate approaches to a brute force "no removal of existing equipment" are available by the removal of the M61A1 cannon or ammunition cannister without seriously deviating from the goals of the flight test program. The F-14A structural test aircraft No. 3 presently does not have a cannon or ammunition cannister. The installation of SOSTEL equipment could be centrally located in a region which would contain adequate volume and would provide cost savings in the SOSTEL installation and subsequent post-flight test reconfiguration of the aircraft.

The SOSTEL system offers significant advantages when applied to a new aircraft or an aircraft undergoing major modifications. Specifically, in the following areas:

- The capability of implementing aircraft design changes by software or limited wiring changes would reduce costs during development and after the aircraft is operational. This capability is available by the addition of new remote terminals for new equipment installations and by changing control equations for existing equipment. The latter implies no rewiring of aircraft to incorporate power control changes

- The SOSTEL BIT features which are designed to isolate problems down to the transducer, controller, and load level as well as the SOSTEL control group equipments, would have a significant impact on the maintenance turnaround time, and preflight readiness checks of a production aircraft
- The ability to program the power priorities of an aircraft as a function of mission or power availability
- The ability to provide "safe" preprogrammed equation states for failed transducers. In addition, the pilots interface allows a means to override a preprogrammed state and effectively gives the pilot an alternate means of selecting switch options
- The capability to automatically and manually reset tripped power controllers as well reconfigure the SOSTEL control group in the event of failures.

The dedicated SOSTEL bus configuration is unnecessary. The relatively low rate of change of SOSTEL information indicates that time sharing of at least one of the channels would still provide adequate capability and protection. In a full up AAES/GPMS aircraft complete time sharing of all channels is adequate. In addition the transfer of information from the MUX terminals to the MU and from the MU to the DEMUX terminals every frame is wasteful of data bus usage. Data should be transferred only when it has new information. This reduces the possibility of transmission errors and utilizes the data bus channels efficiently.

The specified crew control and display panel is not adequate for flight. It is cumbersome and requires look-up tables to decipher the display. A near-term solution is the use of an alphanumeric display or CRT with a software look-up table of mneumonics controlled by a CCDP microprocessor. A future display should be incorporated as part of the Advanced Integrated Modular Instrumentation System (AIMIS) master monitor display.

The SOSTEL MU processor function can be performed by a microprocessor. Our analysis of the requirements as applied to the INTEL 3000 indicates it is adequate to perform the MU function.

The design of SOSTEL configured about the F-14 incurs the penalty of the addition of GPMS terminals which are required to perform the low-power driver and non-SOSTEL signal sampling functions. This would normally be a GPMS intersystem function; six GPMS terminals are required to perform this function in the prototype F-14 SOSTEL system. SOSTEL must be part of a larger data bus (GPMS), all-subsystems configured aircraft. By virtue of the transfer of intersubsystem information, the SOSTEL system becomes more effective. In addition, standard programmable remote terminal designs can be utilized up to the user I/O if a "smart" terminal design approach is utilized.

Greater use of MUX/DEMUX terminals would reduce parts count by sharing common terminal circuitry, and thus reduce weight and volume and increase reliability. The 11 DEMUX and seven MUX terminals would be reduced to 11 MUX/DEMUX terminals. In addition, the fixed 64-input and 64-output configuration of the remote terminals limits their applicability. For an aircraft such as the F-14, whose avionics are primarily located between the forward portion of the pilots cockpit (station 176) and the aft portion of the NFO's cockpit (station 395), terminals having larger capacity would be advantageous. For an aircraft (i.e., E-2C), whose avionics is less centralized, a smaller capacity terminal may be more desirable. A system which can handle either extreme would require a data bus message structure whose data word count is variable. It is recommended that SOSTEL's message structure be reconfigured to conform to MIL-STD-1553 which contains variable word counts.

A weight penalty of 52 lb is caused by the addition of controller heat sink plates. This can be eliminated by suitably designed installation on compartment shelving on a new aircraft. Even this approach is temporary since the final design should include these devices in the user WRA's. The design and application of an aircraft utilizing HVDC would reduce the power dissipation of the solid state power controller and increase their reliability.

The installation and design of the present F-14 aircraft subsystems was not developed for a SOSTEL configured distribution system. As a result, all penalties of the installation of SOSTEL are borne by the SOSTEL system. In a new data bus designed aircraft this can be moderated by tradeoffs identifying the most effective place for changes. Typical of this is the ability to install and distribute avionics without incurring the wiring penalties which ar now incurred when interfacing equipment which are physically distant.

It is not known whether a 270-volt d-c system offers sufficient advantages to outweigh the costs of configuring present user equipment for 270 VDC. It is recommended that a study be performed using the F-14A aircraft as a baseline vehicle to establish the costs of converting user equipment versus the savings incurred by utilization of a HVDC system for a typical aircraft buy. A complete description of the HVDC area which require further study are tabulated in the HVDC section of this report.